INFLUENCE OF TILE DRAINS ON SEDIMENT CONNECTIVITY BETWEEN SHALLOW AGRICULTURAL TERRAIN AND SNYDER'S DTICH, ORWELL, OHIO: BASELINE ASSESSMENT

by

Hannah Stull

Submitted in Partial Fulfillment of the Requirements

for the Degree of

Master of Science

in the

Environmental Studies

Program

YOUNGSTOWN STATE UNIVERSITY

December, 2014

Influence of Tile Drains on Sediment Connectivity between Shallow Agricultural Terrain and Snyder's Ditch, Orwell, Ohio: Baseline Assessment

Hannah Stull

I hereby release this thesis to the public. I understand that this thesis will be made available from the OhioLINK ETD Center and the Maag Library Circulation Desk for public access. I also authorize the University or other individuals to make copies of this thesis as needed for scholarly research.

Signature:

Hannah Stull, Student Date

Approvals:

Dr. C. Robin Mattheus, Thesis Advisor Date

Dr. Felicia Armstrong, Committee Member Date

Dr. Jeffery Dick, Committee Member Date

Alex Czayka, Committee Member Date

Dr. Salvatore A. Sanders, Associate Dean of Graduate Studies Date

ABSTRACT

Sediment transportation through drains/ pipes is not very well understood. High amounts of sediment in waterways can cause over sedimentation as well as effect aquatic organisms. Snyder's Ditch is an altered channel in a former wetland located on Orwell, Ohio that was converted for the purposes of agriculture. Tile drains and outflow pipes were installed to drain the crop fields as well as along the anthropogenic stream. Sediment transportation through the pipes was measured during five rain event from summer of 2013 and the spring of 2014.

Varying landcover encompasses the channel and provides fundamental information on sediment transportation on different terrain. The study is based on seasonal data over the period of one year. Total solids, suspended solids, and volatile solids were analyzed from eight different sampling locations along the stream. Results concluded that the intensity and duration of the rain event decides the sediment/ volatile load outcome as well as the time of year the samples were taken.

ACKNOWLEDGEMENTS

I really could not thank everyone enough for assisting in my research. I am so grateful for Dr. Robin Mattheus for literally guiding me through this project; I could not have done it without him!! I would like to thank Dr. Felicia Armstrong, for her tremendous help in the lab and sampling as well as to send special thanks out to Dr. Thomas Diggins for his participation in field analysis. I would also like to express my gratitude to Dr. Jeffrey Dick. I am very appreciative to the Western Reserve Land Conservancy for giving me the opportunity to research on their site and allowing me to gain valuable knowledge of the area. I want to thank the Geological and Environmental Department at Youngstown State University for all the help I received as well as giving me the opportunity to meet some incredibly wonderful people.

Thank you to all those you have helped and made this research a possibility. I am so honored to have had Zachary Sain for constant support and assisting in field work. A special thanks to Amelia Stull for assistance in the field and lab analysis. I would also like to thank Emily Ankney, Josh Fowler, Mary Barnwell and Mike Norton for all their help either in the field or the lab.

TABLE OF CONTENTS

1. BACKGROUND

2. STUDY AREA

3. RESEARCH QUESTIONS

4. **METHODS**

5. RESULTS

6. DISCUSSION

7. CONCLUSION

LIST OF FIGURES

CHAPTER 1

INTRODUCTION

1.0 Sediment Transport Overview

Sediments can present an environmental concern, particularly in strongly human-modified landscapes, where natural sediment pathways and connectivity tend to be heavily altered (Renschler and Harbor, 2002; Deasy et al., 2009; Houben et al., 2009). Many of the negative effects of sediment loading of streams are attributed to the suspended load of surface runoff from agricultural lands (Stoneand Krishnappan, 1997; Walling and Fang, 2003; Zimmerman et al., 2003). This is because farm and cropland soils are typically loose and highly susceptible to erosion (Laflen, 1991; Deasy et al., 2009; Wischmeier et al., 1971). Conditions of high precipitation and runoff subsequently create a scenario in which agricultural fields stand to lose soils and associated nutrients to streams, creating a variety of negative environmental impacts in downstream waters (Matisoff, 2002; Michael et al., 2005; Macrae et al., 2007). The suspended-load fraction of transport by water, which is comprised of mineral grains and other particulates (such as organic matter) that are carried through the water in suspension, is particularly problematic from an environmental perspective as this type of load can travel far distances with the flow and is linked to diminished stream health (Kunel, 2000; Renschler and Harbor, 2002).

Suspended sediments are also the primary cause of reservoir in-filling, which creates major financial burdens in many areas across the globe and in many cases linked directly to agriculture and other human landscape disturbances (Crowder, 1987; Palmieri et al., 2001; Wang and Hu, 2009; Deasy et al., 2009; Basson, 2010). Understanding sediment pathways and rates of sediment transport in highly erosive areas such as farm/croplands is therefore highly important from land-management and health perspectives given that landscapes are connected and problems involving sediment erosion, transport, and deposition at the local scale can have broader environmental implications.

1.1 Controls on Soil Erosion

Numerous studies have been conducted to help understand soil-erosion rates and the degree to which different land-cover types influence them under various climate and soil scenarios (Nearing, 1998; Micheal et al., 2005; Singh et al., 2006; Macrea et al., 2007; Bracken and Croke, 2007; Marques et al., 2007; Deasy et al., 2009; Lesschen et al., 2009; Lou et al., 2009). It must be stressed that sediment erosion and transport varies tremendously over varying temporal scales. Oeurng et al. (2010), for example, conclude that sediment transport is highly variable at both the seasonal and the event-scale across forested and agricultural terrains; they also show that sediment exhaustion may overprint seasonal trends, attesting to additional complexities of investigating soil loss. Sediment exhaustion occurs when the uppermost layer of soil (i.e. top layer), which is most easily eroded, is removed during an uncharacteristically heavy flow event, limiting the extent to which future erosion can happen during subsequent events (Oerng et al., 2010).

Other studies stress that, in addition to land cover and rainfall, slope and soil type exhibit strong controls on soil erosion and sediment connectivity (Renschler and Harbor, 2002; Michael et al., 2005; Deasy et al., 2009). Vegetation characteristics in particular are taken into consideration when evaluating active sediment erosion and transport processes (Marques et al., 2007). This is because vegetation not only reduces soil erosion but also acts as a buffer to slow down surface-water flow and trap sediment, thereby limiting the degree of sediment transfer across landscapes (Bracken and Croke, 2007). Many studies have incorporated vegetation effects and discuss the role of vegetation in protecting soils and sediments against erosional forces

(Deasy et al., 2009). Riparian buffers, which are strategically grown along waterways to reduce soil/sediment exposure at the bank and limit bank erosion attest to the importance of vegetation cover in evaluating landscape erosion-potential (Deasy et al., 2009; Lesschen et al., 2009).

Vegetation, which varies seasonally, also has many indirect effects on soil erosion that deal with precipitation and runoff patterns (Michael et al., 2005). There are many dependent variables at play to govern the degree to which erosion, transport, and deposition of sediments takes place across a multitude of surficial scales, ranging from individual fields to the watershed scale (Walling, 1983; de Vente et al., 2007). These aforementioned effects and others make understanding landscape connectivity inherently complex and studies at all spatial and temporal scales are needed for a better constraint of how geographic and climatic parameters (soil types, climates, slopes, etc.) interact to drive sediment transport across our terrains.

1.2 Modeling Soil Erosion

Many factors, some of which are strongly convoluted and interrelated, are at play to help drive soil erosion and transport across various landscape types over a variety of temporal scales. In order to help with the evaluation of soil erosion for land management purposes, conceptual and numerical models are constructed that estimate soil erosion and transport as a function of these aforementioned parameters (i.e. vegetation, seasonality, soil type, etc.). Models such as ‘LUCIFS’ (Land Use and Climatic Impacts on Fluvial Systems; Sidorchuk et al., 2003), ‘DRAINMOD’ (Skaggs, 1982), and the Universal Soil Loss Equation (USLE; Wischmeier and Smith, 1978) can emulate soil loss and provide useful and very visual information for land managers to utilize (Renschler and Harbor, 2002; Singh et al., 2006; Singh et al., 2007; Houben et al., 2009; Lesschen et al., 2009; Low et al., 2010). Each model is unique and takes specific parameters into consideration; model applications are thus highly varied and depend on whether soil erosion is to be evaluated at the event-scale or over decades and/or longer timescales. While models are never 100% accurate, they provide a fast analysis for large areas that can help generate ideas of how sediment erosion may be changed under different climate scenarios, for example. This provides a conceptual framework for studying controls on large-scale sediment loss and pollution potentials (Renschler and Harbor, 2002; Singh et al., 2006; Singh et al., 2007; Michael et al., 2005; Houben et al., 2009; Luo et al., 2010).

A common dilemma to soil-erosion model application is presented by the common lack of field data required for model calibration. Models either over- or underestimate actual soil loss given spatial and temporal scaling problems (Nearing, 1998; Lesschen et al., 2009). The need for useful models is particularly large in developing countries that are modifying their landscapes rapidly; the use of the traditional Universal Soil Loss Equation (USLE; Wischmeier and Smith, 1978) has become a popular tool given that GIS-based programs can provide easy tools for modeling at a variety of spatial scales and the ease of data attainability and manageability.

1.2.1 Universal Soil Loss Equation

The USLE is the most widely-used soil-erosion model and was developed for agricultural plots in the Midwest in the 1960s (Renard et al., 2005). It has since been revisited and refined to extend to other types of geographical settings (Hrissanthou, 2005; Marques et al., 2007). Its simplicity makes it easy to use and data requirements are comparatively low, however; although it was developed for agricultural areas it only estimates soil loss due to surface runoff. A problem that commonly arises within agricultural areas is the presence of surficial drainage systems that cannot be accurately factored into the USLE equation. Another problem is encountered in strongly human-modified agricultural areas that are tile-drained as the USLE may underestimate the amount of additional sediment to connecting streams (Stone and Krishnappan, 1997; Singh et al., 2006; Singh et al., 2007; Macrae et al., 2007; Deasy et al., 2009; Luo et al., 2010). Sub-surface drainage systems are commonly used in agricultural fields that retain a substantial amount of surface water (Singh et al., 2006; Macrae et al., 2007; Singh et al., 2007; Luo et al., 2010) and tiled drains are also capable of transporting fine-grained sediments and chemicals from crop fertilizers (Stone and Krishnappan, 1997; Singh et al., 2006; Singh et al., 2007; Macrae et al., 2007; Deasy et al., 2009; Luo et al., 2010).

Some erosion- and sediment-transport models therefore attempt to incorporate tile-drain parameters into model simulations (Singh et al., 2006: Luo et al., 2010), however; better constraint on the role these features play at the field-scale is needed to evaluate their role as facilitators of overall landscape connectivity (Deasy et al., 2009). While GIS-based erosion models have been developed for many different regions across the globe in a variety of geologic settings for a variety of watershed scales and land covers/uses (Dabral et al., 2008; Erdogan et al., 2007; Lufafa et al., 2003; Ozcan et al., 2008; Pandey et al., 2007; Sivertun and Prange, 2003), only surficial sediment-transport processes are generally taken into consideration. Developing an understanding of how subsurface drainage impacts sediment flux would therefore aid in the development of correction factors that may be applied to models such as the USLE.

1.3 Study Objective

The purpose of this study was to determine how sediments travel through low-gradient, human-altered agricultural landscapes by overland flow and tile drains to provide a baseline for future field research and USLE-based modeling of sediment dynamics. The USLE was designed specifically for agricultural terrain (Wischmeier and Smith, 1978) and use of GIS methods and data availability from government sources (USDA, USGS, etc.) has made its application straight-forward; furthermore, GIS-based application of the USLE provides relatively fast analysis and the ability to simulate changes in land use and/or other conditions (Blaszczynski, 2001). This study was designed to evaluate the seasonal and vegetative influences on sediment yields from tile-drained land parcels feeding into a straightened stream channel. Field data and empirically-derived metrics for different sediment fluxes into the channel were compared qualitatively to spatial patterns of high- and low-erosion USLE predictions to provide an assessment of how appropriate the use of this model is in shallow agricultural settings connected via tile drains.

CHAPTER 2

STUDY AREA

2.0 Western Reserve Land Conservancy Site

The study site, situated within Western Reserve Land Conservancy (WRLC) acreage, is located along the border between Trumbull and Ashtabula counties in Orwell Township, NE Ohio (Figure 2.0). This entire site was once a natural wetland habitat that was drained in the early part of the 20th century and has since been modified for a variety of functions agricultural (i.e. crop farming), silvicultural (i.e. tree farming), and aquacultural (i.e. fish farming). Crop fields are adjacent to the stream study site today; however, the site proved unsuitable for agriculture due to its wetland environment and required the installation of a drainage network in the form of a straight, man-made channel, which was constructed in the early 1900s; this N-S running channel was connected to adjacent farm fields with tile drains. Another land-use type in the area has included fish ponds, which can still be seen along the western side of the main channel; however, inactive for many years they are now choked with dense brushy vegetation.

A shooting range once occupied portions of the study site and an ongoing effort to design a remediation project is underway, which would benefit from an understanding of the current sediment transport through the area. Additionally, a unique opportunity is provided to evaluate sediment fluxes across this heavily modified landscape before any measures to change it are in place. As contaminant transport is tightly linked to sediment transport (Macrae,et al., 2007; Singh et al., 2007; Luo et al., 2010), understanding the sediment dynamics of this altered terrain is also important for assessing contaminant flux out of the area. Correspondence with the Western Reserve Land Conservancy has suggested that Lake Roaming Rock, a man-made reservoir ~15 km downstream (i.e. north) of the study site, is experiencing siltation problems.

2.1 Snyder's Ditch, Contributing Watershed, and Channel-fringing Land-cover Types

The network of channels and drainage systems at the Orwell study site were constructed to help drain the original wetland and, subsequently, the shallow farm fields that replaced it. These drains connect to a main channel known as 'Snyder's Ditch', which runs into Rock Creek, located north of State Route 322 (Figure 2.1), ultimately contributing water and sediment to Lake Erie as tributary to the Grande River. The entire watershed connecting to Snyder's Ditch at the uppermost (i.e. northernmost) extent of the Orwell study area (south of State Route 322) is approximately 60 km^2 in aerial extent and includes the entire Orwell study site (i.e. all ditch-proximal farm fields, forests, etc.).

Snyder's Ditch displays little variance in channel shape and flow character along the study site. The incoming flow from the south enters the study area through a culvert, which creates turbulence in the outflow entering the studied channel segment. Small transverse bars have grown vegetation within the ditch here and there are signs of bank failure. The channel deepens around a bend before straightening and running N-S for the remainder of the study area. The northern terminus of the studied channel is again characterized by riffles and turbulence affiliated with the Moore Road bridge and culvert.

The landscape connecting to the ditch is particularly shallow (i.e. is characterized by extremely low gradients). More than 95% of the study site has a grade of less than 2%. There are steeper slopes present on the site but these are man-made features that mostly line the banks of the channel, which have slopes up to 50 degrees, which is also reflected in high SL-values, which are computed for a USLE analysis from slope and slope-distance maps (Figure 2.2). Snyder's Ditch is around 10 km long and runs north to south across the study site, connecting to individual farm fields and other plots through tile drains and pipes (Figure 2.1).

The land-cover distribution within the entire watershed area is comprised of ~ 28 % forestland, ~30 % cropland, and ~20 % wetland areas. The remaining landscape is a mix of pasture and shrub-land. The areas immediately fringing Snyder’s Ditch are largely agricultural as this area was drained for that particular purpose; fields covered by row crops fringe the entire eastern portion of the channel along the southern extent of the study area, south of the tributary juncture with another channel after which forestland replaces this land-cover type along the eastern banks. The western side of Snyder’s Ditch houses pastureland, remnant wetlands areas that are separated from the channel by man-made berms, and basins created for fish farming, which have largely filled in with vegetation and appear to only pond water after rain events (Figures 2.2).

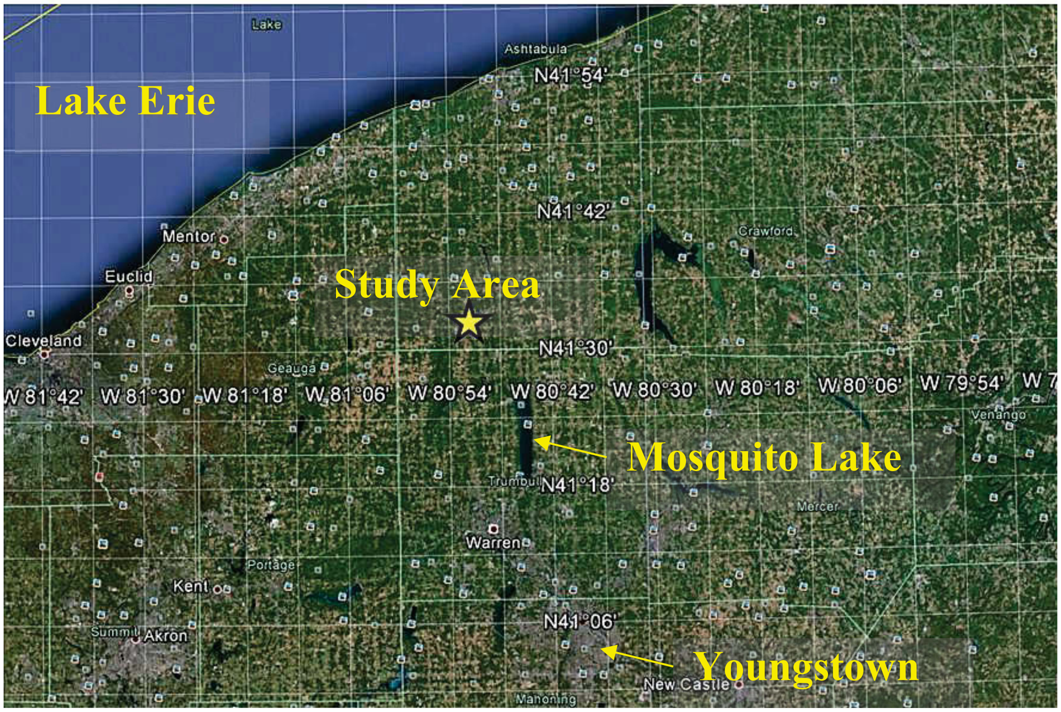

Figure 2.0 - This Google Earth map of NE Ohio showing the location of the Orwell study site (i.e. the Western Land Conservancy property by Orwell). Features are labeled for orientation. An aerial view of the site is shown in Figure 2.1.

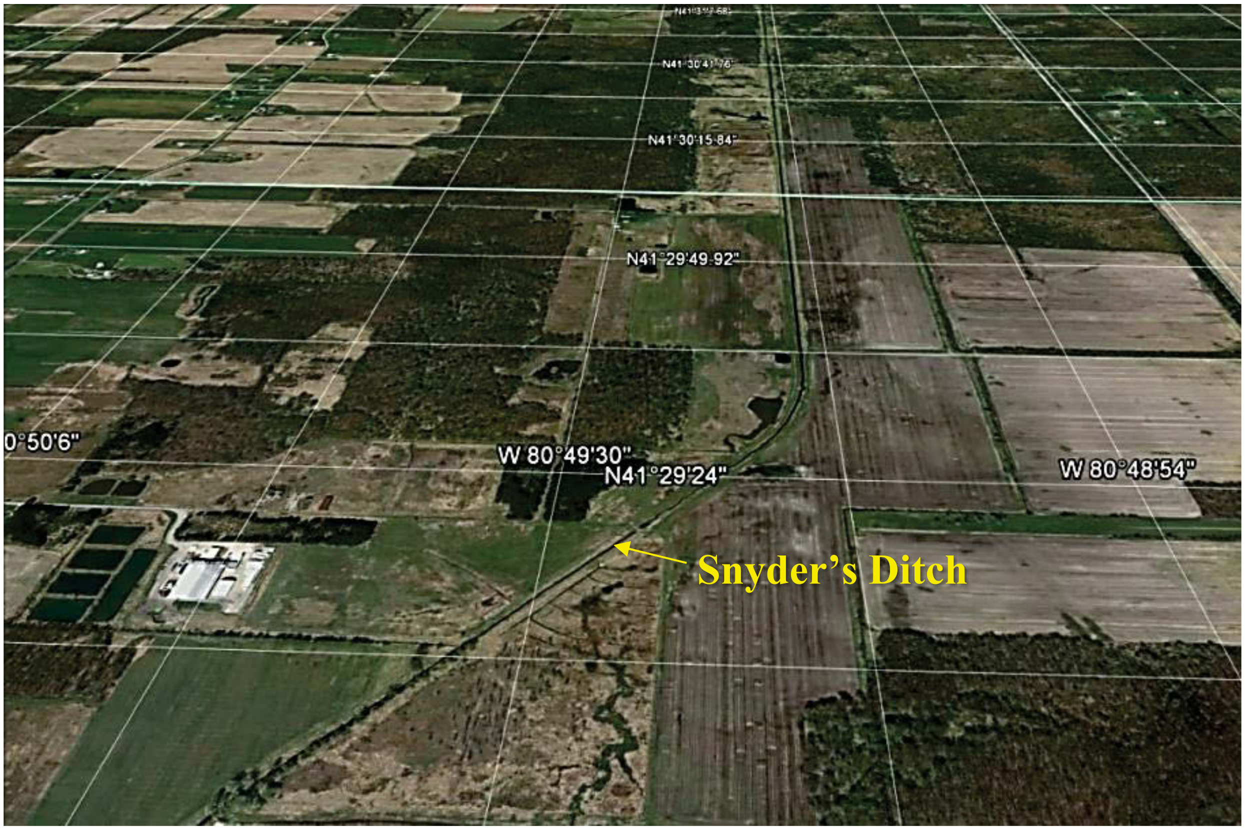

Figure 2.1 - Google Earth image showing 'Snyder's Ditch' and surrounding terrain, largely utilized as pastureland and/or cropland. The image is a snapshot taken at an oblique angle to the ground looking directly northward from the southern-most extent of the study area, just south of the bend in the channel.

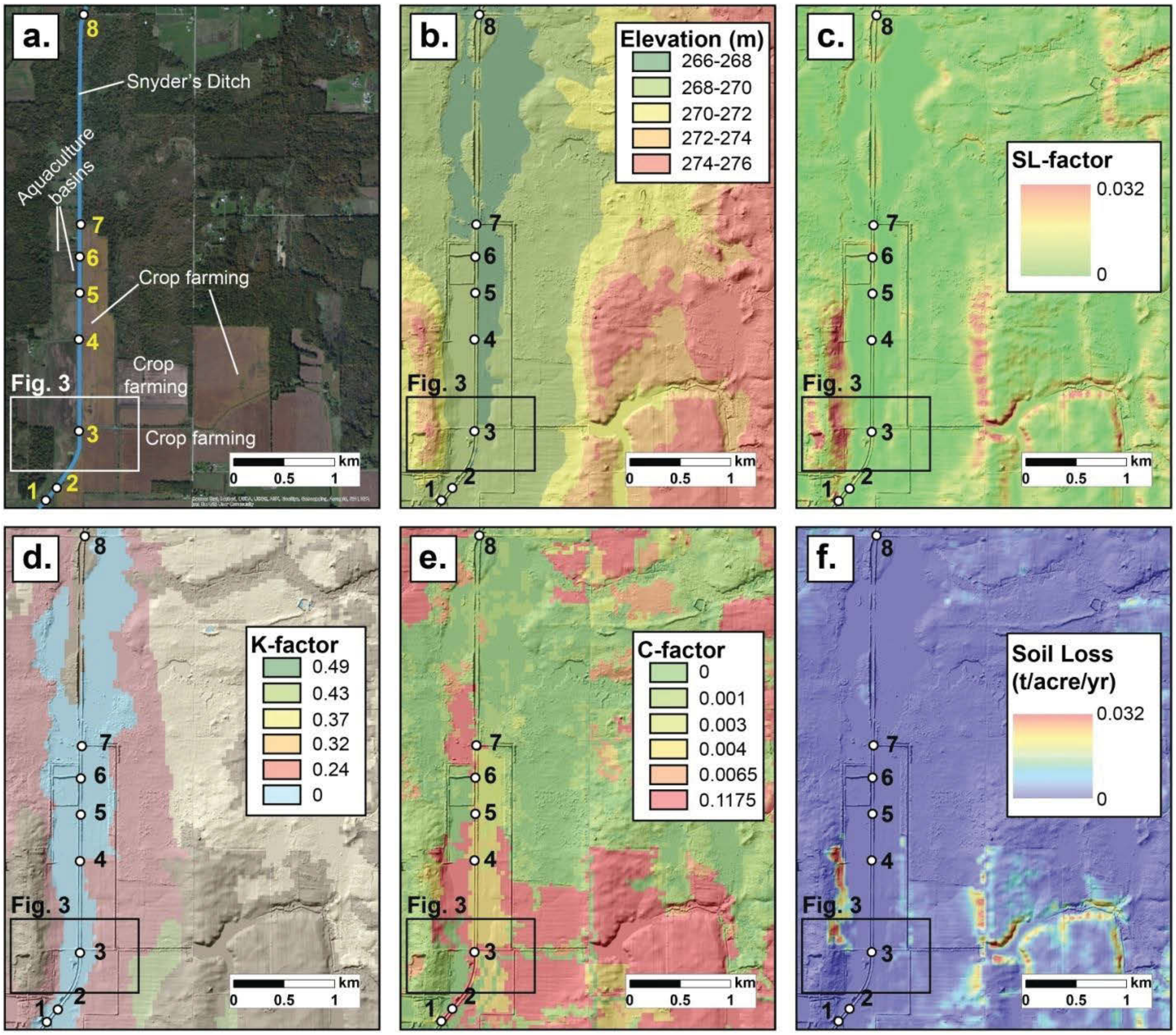

Figure 2.2 - Maps of the studied corridor along Snyder's Ditch showing: a) an aerial view of the area with key land-cover types labeled, b) color-coded elevation ranges based on a 30 m USGS dataset, c) the USLE SL (slope and slope length) factor based on a workflow devised by REF, d) K-factor value distributions based on information on USDA soil data, e) C-factor values based on land-cover types assessed using the 2006 USGS landcover dataset (at 30 m resolution), and f) the resulting estimated mean annual soil loss based on the USLE and the data presented in parts c, d, and e of this figure. The analysis follows the approach of Mattheus and Norton (2013) and utilizes the same data sources. The output soil-loss estimate is given in tons/acre/year. As this study is not designed to quantify sediment fluxes over a one-year period this map simply serves to provide an idea of where erosional hotspots may be located and whether or not analyzed water samples provide insight into the nature of soil erosion and landscape connectivity in corroboration with USLE model parameters. For station names (1-8), refer to Appendix E.

CHAPTER 3

RESEARCH QUESTIONS

3.0 Research Parameters and Goals

One problem with assessing sediment yields is that erosion is sometimes buffered by vegetation or deposition within a watershed (Walling, 1983; deVente et al., 2007). This buffering effect is likely diminished at the Orwell site because fields here are more directly connected to the ditch through tile drains. It is likely that popular soil loss models such as the USLE therefore underestimate sediment contributions from these fields. While ponds and fields would ordinarily sequester sediment, it is exported through the pipes, which can be sampled directly to provide an idea of sediment flux to the main channel. As tile drains are designed to remove excess water from the fields, they should generally have the capacity to facilitate sediment transport as well. The exact effects on sediment fluxes at the Orwell site are not yet constrained, although it appears that the channel and downstream reservoirs, such as Rock Creek, are silting in from an increase in sediment loading, suggesting an increased connectivity between shallow landscape and channel. A baseline sediment study of outflow from individual fields is designed to shed light into the nature of transport through this type of environment as a comparison to USLE-derived estimates of soil erosion for the area. As little is previously understood about Snyder's Ditch's sedimentation transport and landscape connectivity, this investigation focuses on addressing a collective set of questions devised to help direct research efforts at the site:

- How well-connected is this shallow landscape from a sedimentary perspective?
- What are seasonal effects on sediment yield across different land-cover types?

- How do GIS-based estimates of sediment yield and field data compare and do sedimentologic data from Snyder's Ditch corroborate USLE estimates, qualitatively?

CHAPTER 4

METHODS

4.0. Sedimentary Analyses

These study questions were addressed using empirical data evaluated from storm-water samples collected from 8 stations along Snyder's Ditch (Figures 2.2 and 4.0) during select rain events (Appendix 1-4). Water samples were analyzed for Total Solids (TS), Total Suspended Solids (TSS), and Total Volatile Solids (TVS). Raw data from these analyses are shown in Appendices 1-3. Trends in these metrics over time and space were subsequently evaluated against USLE model results qualitatively using ArcGIS 10.1. The USLE model was provided and derived following the method in Mattheus and Norton (2013) using soil, slope, and landcover information from USDA and USGS sources. Grab samples from the channel bottom at select locations furthermore provided sedimentologic data for better site characterization and discussion. The following sub-sections detail the specifics regarding each individual sediment analysis undertaken.

4.0.1 Surveying

Field surveying was employed in an effort to characterize the landscape connectivity between Snyder's Ditch and adjacent fields by locating and mapping tile drains and/or other man-made drainage features and determining their particular functionality. Field reconnaissance was aided by GIS maps constructed from air-borne LIDAR and aerial images within ArcGIS. GPS coordinates collected in the field for features of interest such as tributary junctions, tile-drain confluences, etc., enabled the delineation of sub-watersheds or areas contributing discharge to Snyder's Ditch at different locations along its course. The eight monitoring (i.e. sediment sampling) locations shown in Figures 2.2 and 4.0 were based on nodes of interest along this route that subdivided adjacent farmland into water and sediment-contributing parcels.

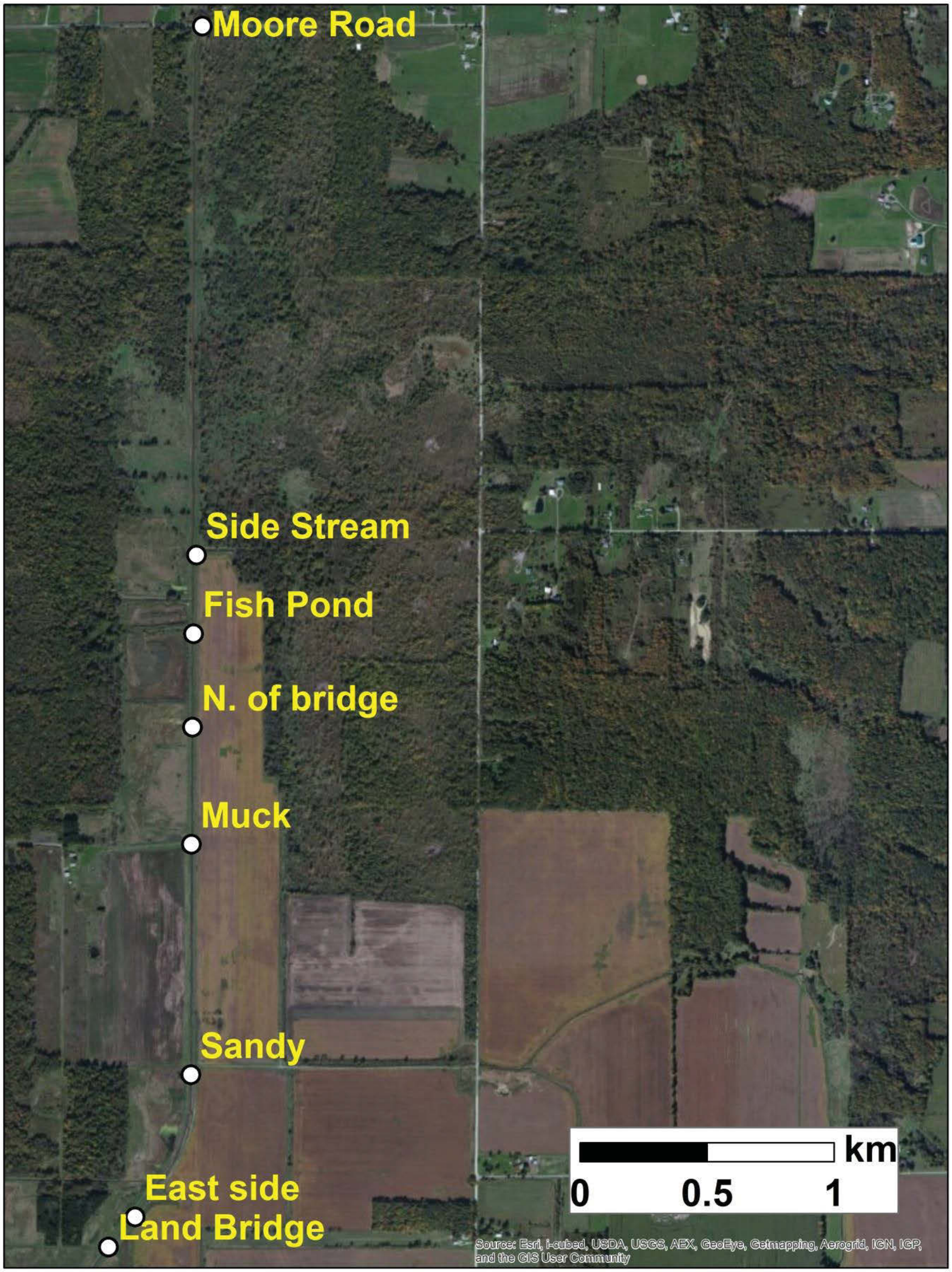

Figure 4.0 – Map of the 8 sampling locations revisited on a seasonal scale. For station names (1-8), refer to Appendix E.

4.0.2 Stream Monitoring and Sampling in the Field

Areas of sediment contributions to sample locations are constrained as these were selected based on active tile-drain locations and implied connectivity to adjacent farmland parcels. Storm water was collected from pipe outflow during rain events across a seasonal spectrum (spring, summer, fall, and winter). The following paragraphs detail site-specific details of the sampling dates for each of the 8 sampling locations, which span the ~4 km long study area at near-equal spacing (Figure 4.0).

The 'Land Bridge' (Site 1) was the southernmost sampling location and represents the upstream (i.e. up-channel) limit of this investigation. Samples here were taken directly from the center of the stream in front of the pipe end where the fastest part of the flow was centered. This sample location provides a measure of sediment content of incoming water (from upstream) before subsequent sedimentary point sources connect to the ditch from the surrounding farm fields and other downstream plots (Figures 2.4 and 4.0). It must be noted that the water sampled flows from a large culvert that runs under a small land bridge connecting eastern and western fields (Figure 4.1).

Figure 4.1 – 'Land Bridge' (Site 1) sampling pipe. Figure 4.0 shows the location of the site on Snyder's Ditch. Water was sampled several m downstream of the pipe.

The ‘Down Stream of Land Bridge’ (Site 2) sampling location (referred to as ‘Sandy’ in the subsequent sediment analyses) is located just north (i.e. downstream) of the ’Land Bridge’ sampling site. The stream at this location receives water and sediment contributions from cultivated farm fields situated to the east of the channel (Figure 4.0). These farm fields drain into Snyder’s Ditch through a tile-drain and pipe system, the outlet of which served as the sampling location (Figure 4.2).

Figure 4.2 - Photograph of the outflowing pipe at ‘Downstream Landbridge’ (Site 2) where the samples were collected from. This pipe connects to farm fields situated to the east of the channel. Figure 4.0 shows the location of this sampling site.

The ‘Down Stream Land Bridge’(Site 3) sampling location (known as ‘East Side’ in the subsequent sediment analysis) is situated adjacent to an outflow depression connecting surface drainage from the east and northeast, which encompasses farm fields primarily used for row cropping. Samples were taking directly downstream of the outflow from the center of the stream. There is a slight depression within this cultivated farmland adjacent to the berm flanking Snyder’s Ditch, which is blown out at this location, providing a direct drainage pathway for surface-water flow (Figure 4.3).

Figure 4.3- This is the 'East Side' (Site 3) sampling location. The view is from the west bank of Snyder's Ditch toward the opposite bank, where a blowout reveals a surficial connection to the adjacent farmland. Samples were taken from the center of the channel immediately downstream of this location. Figure 4.0 shows the location of this sampling site. A rill is shown connecting the row crop fields to Snyder's Ditch.

The 'Wooden Bridge' (Site 4) sampling site (referred to as 'Muck" in the subsequent sediment analyses)' is the next northward sampling location (Figure 4.4). The outflow water is coming from the fields and is the last sample that ties the connectivity to row crop contribution to sediment loads. The samples were taken from the center of the stream at this location due to a lack of direct point source (i.e. surficial connection as is the case with the 'East Side' location or outflow pipe) along this particular stretch of the channel. The sampling location was chosen to provide a more uniform data coverage along channel gradient and provide a measure of sediment concentrations away from direct sediment inputs (i.e. drains).

Figure 4.4- The 'Muck' (Site 4) site shown here was sampled just south of the wooden bride from the center of the channel (not a pipe sample). Figure 4.0 shows the location of this sampling site.

‘Downstream Wooden Bridge’, (Site 5) (known as ‘Pipe North of bridge’) is another sampling location situated just downstream of an inflow pipe (Figure 4.5).Water and sediment at this location are funneled in primarily from the west across a pastured, grassy area that is characterized by a very dense vegetation cover (Figure 4.5), which stands in stark contrast to farm fields that line the southerly stretches of the study area, particularly along the eastern banks of the channel (Figure 4.0). This site was hence chosen to provide a comparison to the sites experiencing row cropping, which should have more bare soil exposed for much of the year.

Figure 4.5 - Photograph showing the approach to the ‘Pipe North of bridge’ (Site 5); more specifically, the photo shows a pool of water backing up to the pipe that connects to Snyder’s Ditch, located to the right of this feature from this viewpoint. Figure 4.0 shows the location of this sampling site.

The ‘Fish Ponds’(Site 6) situate north of the ‘Pipe North of bridge’ site is adjacent to several basins once utilized for fish farming; the land cover here is now characterized by a mix of pasture, shrubs, and water (i.e. ponds). The fish farming operation has long been abandoned and much of the area (i.e. many of the basins) is choked with dense brushy and grassy vegetation (Figure 4.0). Snyder’s Ditch should receive sediments from across this area through a pipe that is shown to clearly connect this landscape to Snyder’s Ditch (Figure 4.6).

Figure 4.6 - Photograph of the 'Fish Pond' (Site 6) sampling site, situated just downstream of an outflow pipe connecting to former fish farm basins. The sampling location is shown in spatial context in Figure 4.0.

'Side Stream' (Site 7) is a more northerly sampling site characterized by channel confluence as an incoming ditch enters the main N-S trending channel of Snyder's Ditch from the east (Figure 4.0). Samples here were collected just before the juncture from within the smaller side stream in order to elucidate its sediment contributions during rain events to Snyder's Ditch (Figure 4.7). This tributary channel connects to additional tile drains and areas to the east of Snyder's Ditch, including which includes forested areas (Figure 4.0).

Figure 4.7 - Photograph showing the tributary confluence at study site 'Side Stream' (Site 7). Samples were taken directly from the center of the tributary 'Side Stream'. The sampling location is shown in spatial context in Figure 4.0.

The 'Moore Road'(Site 8) represents the northern-most sampling point; water and sediment samples here were taken from the center of the stream just past the Moore Road Bridge. The surrounding land cover is very different from those of the other sites as much of the stretch between the 'Side Stream' site and 'Moore Road' is wooded (Figure 4.8).

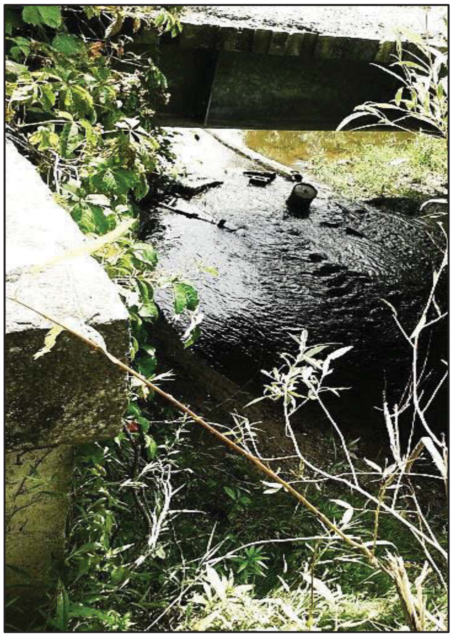

Figure 4.8- Pictured here is the sampling site for 'Moore Road' (Site 8). The sampling location was located on the downstream side of the Moore Rd. Bridge.

4.1 Grain-size Analysis and Channel-bottom Sediment Distribution

Sediment grab samples were taken with a ponar grab sampler during base flow conditions from the channel bottom at seven sampling locations that were close to equally spaced along Snyder's Ditch; samples were used to evaluate the sediment particle-size distribution along the channel bottom. Samples were evaluated for their grain-size distribution by laser-diffraction using a CILAS 1180 particle-size analyzer housed at the Youngstown State University Sedimentology Lab. As this unit measures grain sizes over a spectrum of 0.2 to 2,500 microns, any gravel-sized particles present in the sample, generally considered to represent rubble introduced at bridge crossings unaffiliated with sediment contributions from overland flow from farm fields, were omitted from the analysis and separated using 2 mm sieves. The sedimentary analysis thus focused solely on the distribution of the muddy and sandy sediment fractions and their spatial variance along the channel bottom.

4.2 Water and Sediment Analyses in the Lab

Water samples were brought to the lab facilities, housed within the Department of Geological and Environmental Sciences at Youngstown State University, for sediment analysis. The following paragraphs detail the lab methods involved in quantifying sediment loads, which included assessments of a) TS, b) TSS, and c) TVS. All analyses were performed at the lab facilities housed at Youngstown State University.

4.2.1 Total Solids (TS)

The TS procedure cited in Standard Methods, 20th Edition (edited by Clescerl et al., 1998) was employed on collected water samples. These standard methods were followed in every case to ensure accuracy between samples per given sampling event and between sampling events. In order to perform these tests, empty crucibles were weighed before adding the sample. Twenty- five milliters of water sample (from the different sampling locations) was poured into them for subsequent analysis. Water-laden crucibles were put into a standard sediment oven set to 105ºC for 24 hours. Crucibles were weighed after cooling. The weight differential between baked crucible (formerly containing the water sample) and the initial crucible weight was calculated to represent a measure of TS.

4.2.2 Total Suspended Solids (TSS)

The TSS procedure was conducted adhering to the Standard Methods, 20th Edition (edited by Clescerl et al., 1998). In this analysis 300ml of the water samples were run through the preweighed filter papers (Figure 4.9). After the samples were filtered, filter papers were placed in the sediment oven at 105º C for 24 hours and subsequently weighed (after cooling). The weight differential between baked sediment-laden filter paper and recorded initial weight was recorded to represent a measure of TSS.

Figure 4.9 - Tray of filter papers containing suspended sediments filtered out of collected water samples.

4.2.3 Total Volatile Solids (TVS)

The procedure was directly adapted from the Standard Methods, 20th Edition (edited by Clescerl et al., 1998) and provided the total amount of volatile content (i.e. organic matter) in each sample. The crucibles containing the total solid content (from the TS procedure) were required for this analysis. The baked crucibles from the TS analysis containing the total amount of solids were placed into an incinerator set to 550ºC for one hour. Crucibles were weighed after cooling and the difference in pre- and post-incineration weight provided a measure for the amount of organic matter in the samples (TVS), respectively.

CHAPTER 5

RESULTS

5.0 Storm-water Data

The following sections document details regarding individual sampling events and the sedimentologic data they generated. Attention was given to recording the timing of sampling for potential future evaluation with respect to precipitation data and/or inferred discharge conditions for Snyder's Ditch, for which no gage station exists. Raw data are listed in appendices while GIS-based maps based on those data are provided for easy spatial visualization of sediment constituencies in water samples collected along Snyder's Ditch.

5.1 Bottom Sediment Distribution

Particle-size analysis reveals the spatial distribution of mud and sand along Snyder's Ditch; the samples were bimodal and contained sand and clay. The channel is muddier towards the southern study area extent, where clay constituency is around 93%, and coarsens toward the north, where clay constituency is around 26% (Figure 5.0).

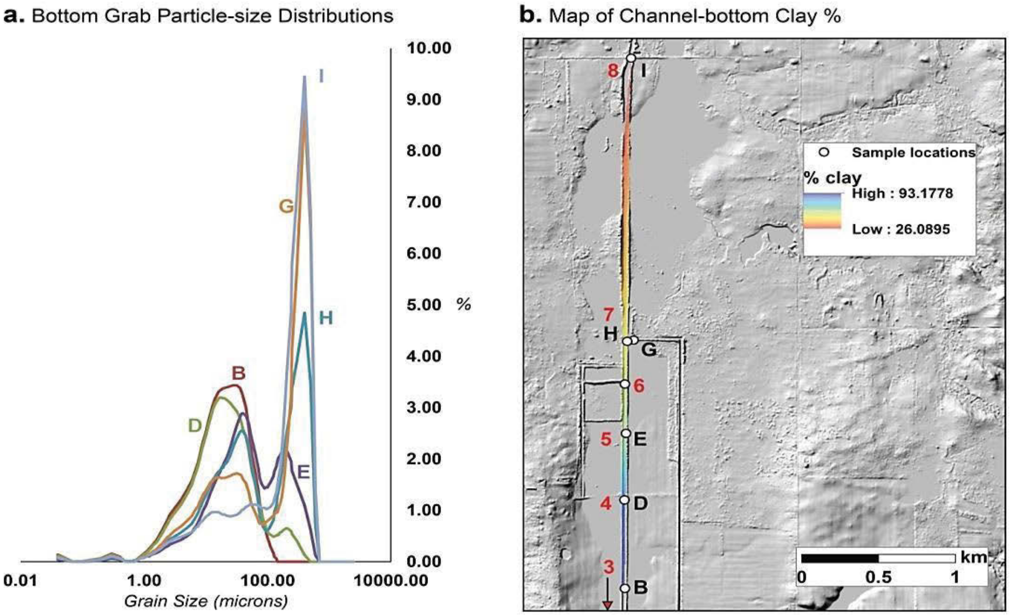

Figure 5.0 Graph (a) representing the grain-size distributions for select samples (named B, D, E, G, H, and I). Map (b) indicating were the high and low clay content is located based on the laser-diffraction study.

5.2 Base Sampling: May 28th, 2013

The purpose of this sampling was to evaluate sediment concentrations in Snyder's Ditch at the sampling locations at low-flow conditions unaffiliated with recent precipitation. This data provides a glimpse into ambient conditions at the site and serves as a control for much of the days separating larger flow events, many of which were sampled.

5.2.1 Sampling Conditions

Samples were collected between 11:00 AM and 3:00 PM; weather conditions were as follows: with some cloud coverage and slight sun. Temperatures were around the low 80 º F. The conditions of the water in the channel were as follows: dissolved oxygen was at 54% and was 4.38 mg/l, the conductivity of the water 324.7 micro Semans, the temperature was 23.1 º C, the pH measured at 7.8, and the depth of the channel ranged from less than ~0.3 m to over ~2.5 m; the tributary 'Side Stream' was measured to have depths between 1 and 1.5 m near the confluence.

5.2.2 TS Data

TS for the 8 sites ranged between ~0.215 g/l and ~0.286 g/l. The highest value was from site 'Muck' (Appendix A) and the lowest value came from sites 'Side Stream' (Appendix A) while the average was ~0.249 g/l (Appendix A; Figure 5.1).

5.2.3 TSS Data

TSS for the 8 sites ranged between~ 0.002 g/l and~ 0.025g/l. The highest value was measured for site 'Moore Road' while the lowest were found at sites 'Sandy', 'Muck', and 'Fish Pond' (Appendix B). The average for the TSS was ~0.006g/l (Appendix B; Figure 5.1).

5.2.4 TVS Data

TVS ranged between~ 0.013 g/l and~ 0.092 g/l while the average for all the sites was measured to be ~0.045 g/l (Appendix C). The highest value came from the 'East Side' site (Appendix C) and the lowest came from 'Side Stream' (Appendix C; Figure 5.1).

.

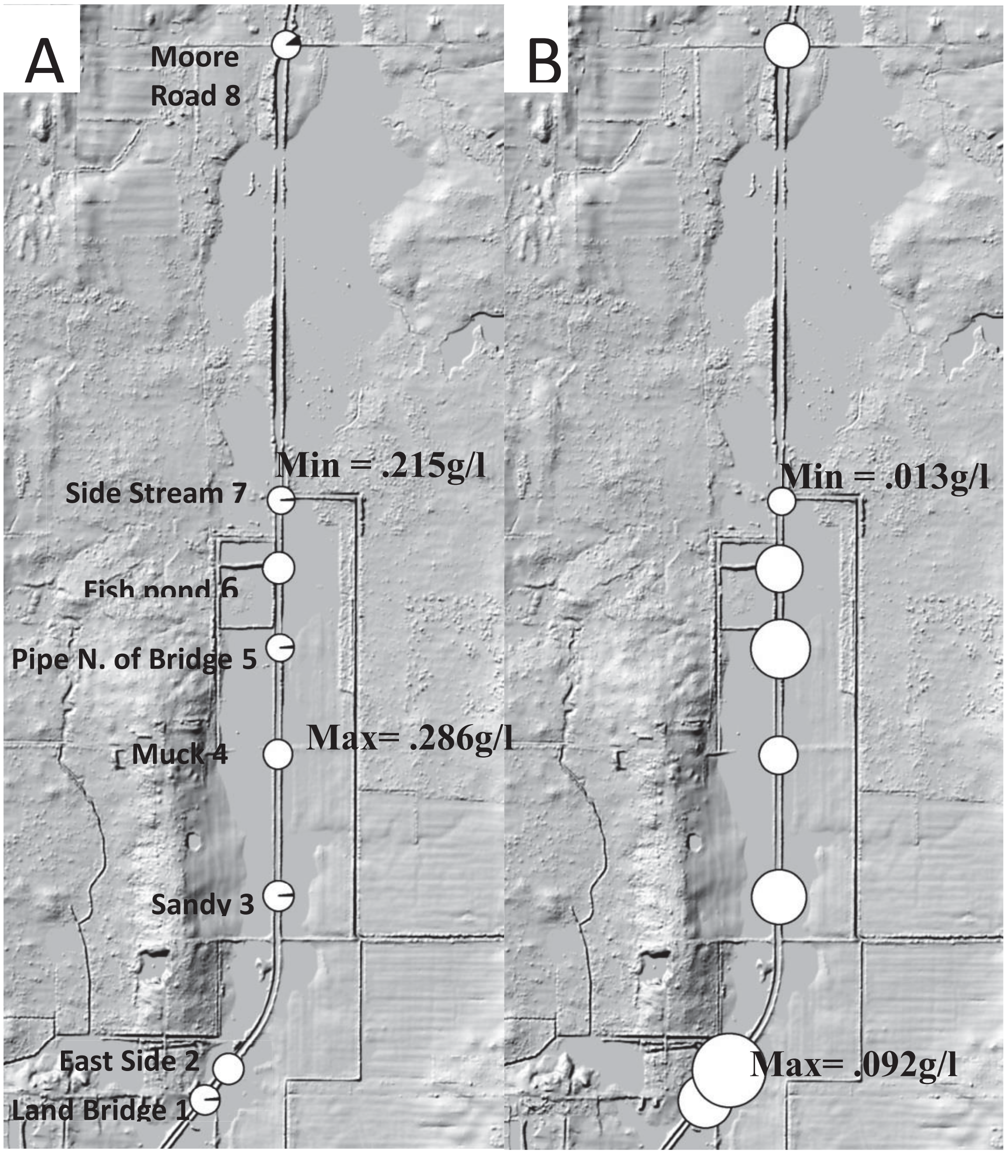

Figure 5.1 - Map showing pie graphs created from TS, TSS, and TVS data for the base sampling event. The size of the pie chart is scaled to the total amount of sediment retrieved out of 1 liter of water. Map A shows the dissolved solids (white) compared to the suspended solids (black), which comprise the TS. Map B is volatile solids. For the exact data refer to Appendix A-C.

5.3 1st Sampling: July 12th, 2013 (Summer Sampling 1)

5.3.1 Sampling Conditions

This is the first rain event that was targeted for sampling and presents one of two summer events sampled. The samples from this particular outing were collected after a 7 day rain/ storm event. Sampling took place from 11:00 AM to 3:00 PM on July 12th, 2013. The temperatures were in the high 80s º F with high air humidity. The water in the channel was between 2 and 2.5 m deep on average with the 'Side Stream' slightly exceeding 1 m in depth. The water levels were so high in the channel that the 'Fish Pond' and Pipe North of bridge' sampling sites were completely submerged. The vegetation on the northern section of the channel (from the 'Wooden Bridge' to 'Moore Road' sampling locations) was very dense and over 2 m tall (Appendix A-D).

5.3.2 TS Data

TS for the 8 sites had a range between ~0.106 g/l and ~0.243 g/l (Appendix A). The highest value was obtained from site 'Pipe N. of Bridge' (Appendix A) and the lowest value came from the 'Sandy' site (Appendix A). The average for all sites was ~0.140 g/l for this summer sampling event (Appendix A; Figure 5.2).

5.3.3 TSS Data

TSS for the 8 sites ranged between ~0.012 g/l and ~0.181g/l (Appendix B). The highest value was site 'Pipe N. of Bridge' (Appendix B) while the lowest was found at the 'Side stream' site. The average for the TSS for all sites was ~0.038 g/l (Appendix B; Figure 5.2).

5.3.4 TVS Data

TVS ranged between ~0.002 g/l and ~0.053 g/l for all sites with an average of ~0.022 g/l (Appendix C). The highest value represents the 'Pipe N. of Bridge' sample while the lowest came from the 'Muck' sample (Appendix C; Figure 5.2).

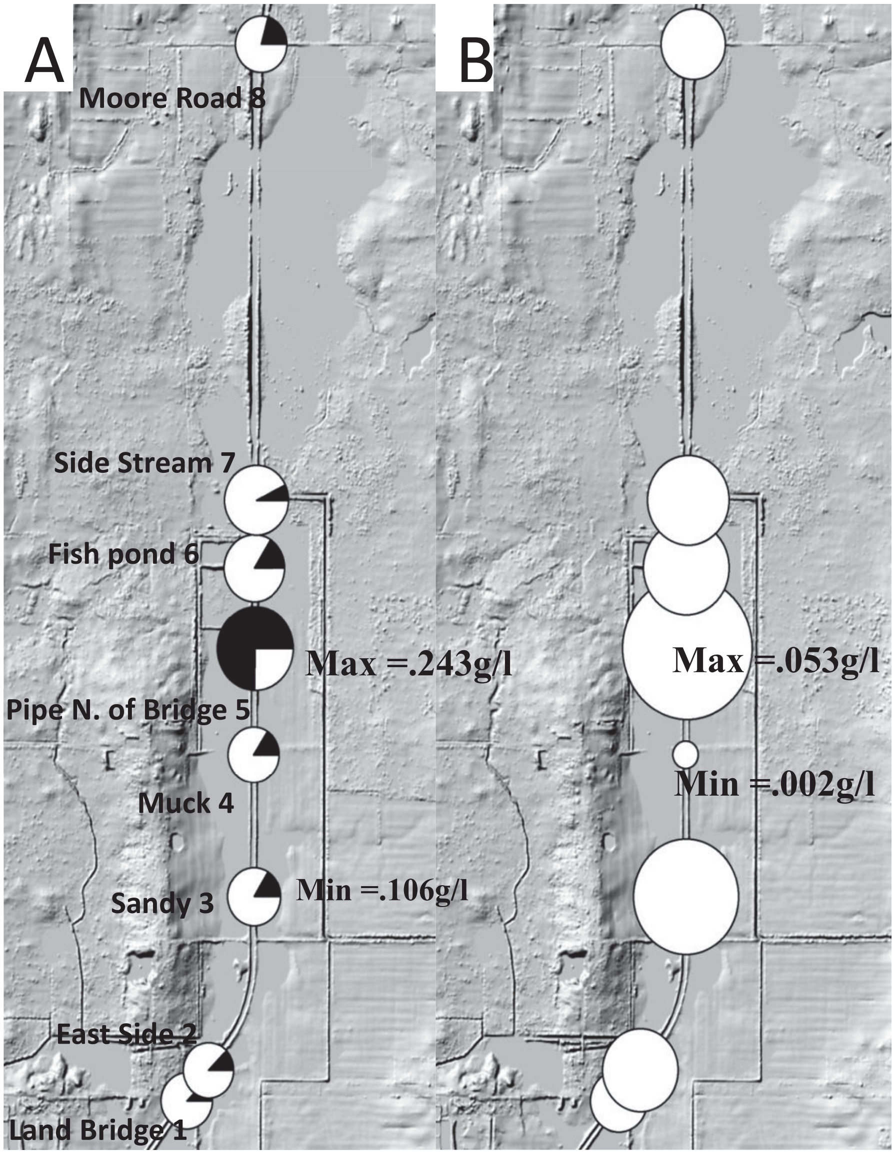

Figure 5.2 - Map showing pie graphs created from TS, TSS, and TVS data for the 1st summer sampling event. The size of the pie chart is scaled to the total amount of sediment retrieved out of 1 L of water. Map A portrays the dissolved solids (white) against the suspended solids (black, which comprise the TS). Map B are the volatile solids. Refer to Appendix A-C.

5.4 2nd Sampling: August 9th, 2013 (Summer Sampling 2)

5.4.1 Sampling Conditions

Previous to sampling, it had rained for two continuous days and weather conditions during sampling, which took place between 11:00 AM and 2:00 PM on August 9th, 2013, where characterized by sprinkling/misting rain. The temperature was measured at 73 º F and atmospheric conditions were very humid with scattered patches of fog observed. Vegetation was lush and dense in the northern section of the channel, as previously observed during the 1st summer sampling event (on July 12th). Water levels in Snyder's Ditch were observed to be lower during this sampling than during the previous, with water levels around 2 m and 'Side stream' between 1 and 1.5 m. (Appendix A-D).

5.4.2 TS Data

TS for the 8 sites had ranged between ~0.084 g/l and ~1.260 g/l (Appendix A). The highest value was from site 'Pipe N. of Bridge' while the lowest value came from 'Land Bridge'. The average was ~0.442 g/l (Appendix A; Figure 5.3).

5.4.3 TSS Data

TSS for the 8 sites ranged between ~0.013 g/l and ~0.176 g/l (Figure 5.2; Appendix B). The highest value was site 'Land Bridge' while the lowest was found at the 'East Side' (Figure 5.3; Appendix B). The average for the TSS concentration among all sites was calculated to be ~0.052 g/l (Appendix B; Figure 5.3)

5.4.4 TVS Data

TVS ranged between ~0.004 g/l and ~0.011 g/l while the sites averaged ~0.008 g/l (Figure5.2; Appendix C). The highest value came from the 'Moore Road' and 'Land Bridge' sites while the lowest came from 'Muck' (Appendix C; Figure 5.3).

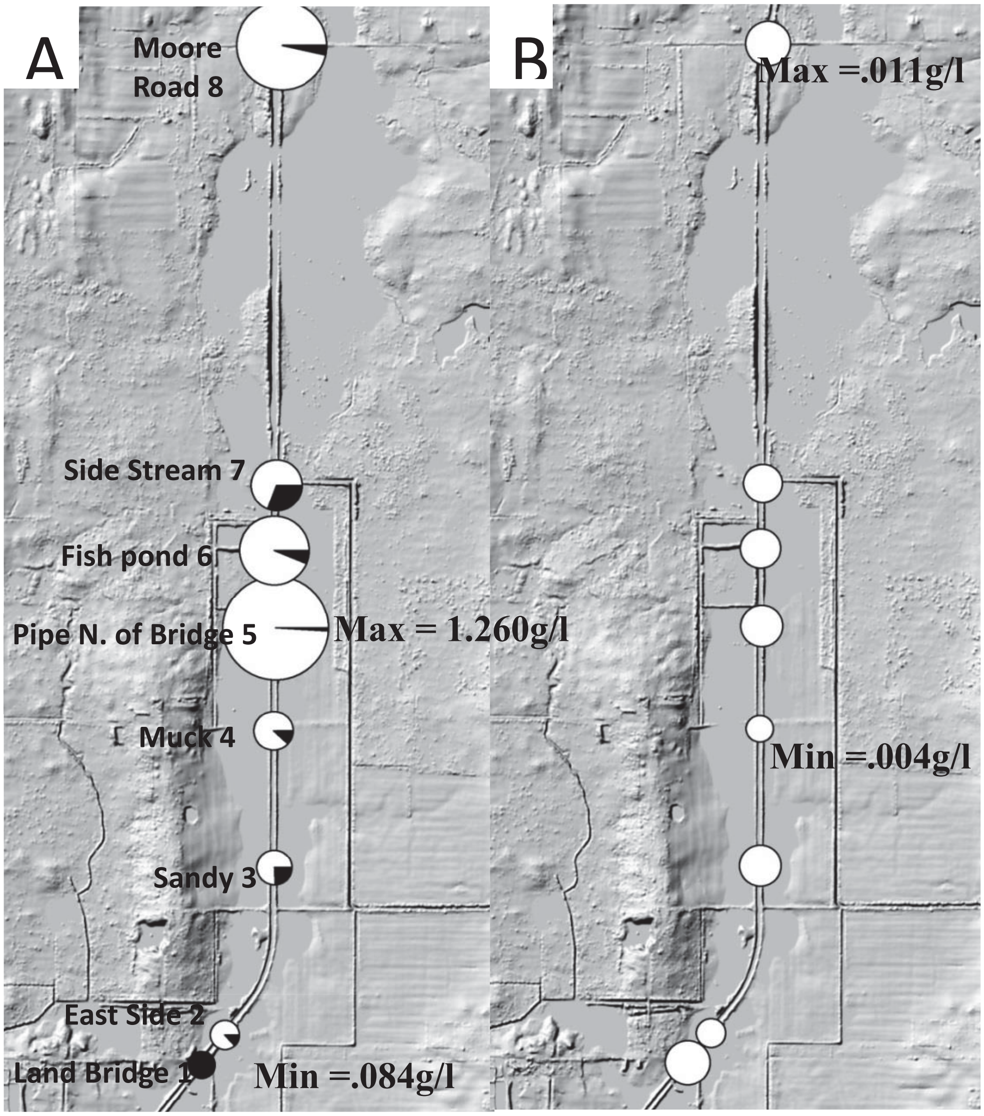

Figure 5.3 - Map showing pie graphs created from TS, TSS, and TVS data for the second summer sampling event. The size of the pie chart is scaled to the total amount of sediment retrieved out of 1 ml of water. Map A portrays the dissolved solids (white) against the suspended solids (black), which comprises the TS. Map B are the volatile solids. Refer to Appendix A-C.

5.5 3rd Sampling: September 22nd, 2013 (Fall Sampling)

5.5.1 Sampling Conditions

A rain event took place Saturday, September 21st (2013) from 4:00 AM to around 8:00 PM. Sampling took place the following morning between 9:00 AM and 11:00 AM. The temperature was measured to be ~52 º F during sampling with slight mist and cloud coverage defining the conditions (Appendix A-D).

5.5.2 TS Data

TS for the 8 sites ranged between ~0.180 g/l and ~0.460 g/l (Figure 5.3; Appendix A). The highest value was from the 'Fish Pond' site and the lowest value came from the 'Moore Road' site. The average calculated for all sites is ~0.28 g/l (Figure 5.4).

5.5.3 TSS Data

TSS for the 8 sites ranged between ~0.005 g/l and ~0.233 g/l (Figure 5.4; Appendix B). The highest value was site 'Fish Pond' while the lowest was found at the 'Moore Road' site (Appendix B). The average for the TSS between all samples for this sampling interval was calculated to be ~0.069 g/l (Appendix B; Figure 5.4).

5.5.4 TVS Data

TVS ranged between~ 0.086 g/l and ~0.146 g/l (Appendix C; Figure 5.4) while the sites averaged ~0.116 g/l (Appendix C). The highest value came from the 'Muck' while the lowest came from the 'Side Stream' site (Appendix C).

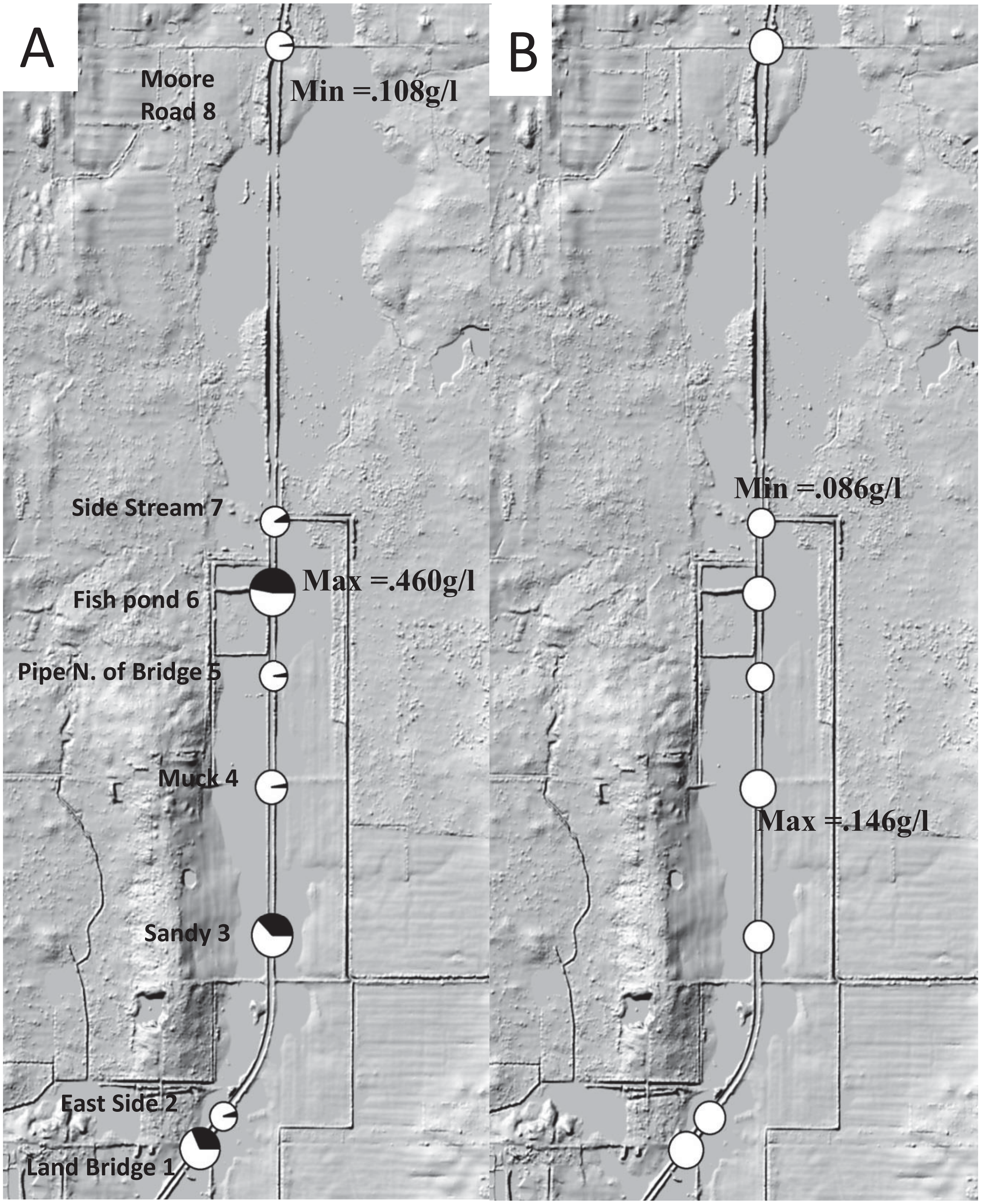

Figure 5.4 - Map showing pie graphs created from TS, TSS, and TVS data for the fall sampling event. The size of the pie chart is scaled to the total amount of sediment retrieved out of 1 ml of water. Map A portrays the dissolved solids (white) against the suspended solids (black), these comprises the TS. Map B are the volatile solids. Refer to Appendix A-C.

5.6 4th Sampling: February 21st, 2014 (Winter Sampling)

5.6.1 Sampling Conditions

The day before sampling temperatures rose enough to induce a high amount of snowmelt. In addition, thunderstorms characterized this day before, aiding this melting process in addition to providing additional water for runoff. Sampling took place from 8:00 AM to 11:00 AM on February 21st, 2014. The water in Snyder's Ditch was measured at ~7 feet. The fields on the west side of the channel were largely flooded and housed standing water, which was more prevalent towards the 'Land Bridge' site (Figure 4.0) Vegetation cover was minimal given the time of season. The 'Pipe north of land bridge' site was submerged while the 'Fish Pond' sampling pipe was completely frozen at its outflow location; these samples were therefore taking adjacent to the pipes (within Snyder's Ditch) as opposed to directly from the outflow pipe (Appendix A-D).

5.6.2 TS Data

TS for the 8 sites had a range between ~0.028 g/l and ~0.164 g/l (Figure 5.5; Appendix A). The highest value was from the 'East Side' site while the lowest value came from the 'Sandy' site. The total average for this sampling interval was ~0.093 g/l (Appendix A).

5.6.3 TSS Data

TSS for the 8 sites ranged between ~0.007 g/l and ~0.036 g/l (Figure 5.5; Appendix B). The highest value was found at the 'Moore Road' site while the lowest was found at the 'Muck' site. The average for the TSS across all locations was ~0.014 g/l (Appendix B).

5.6.4 TVS Data

TVS ranged between ~0.036 g/l and ~0.170 g/l while all the sites are characterized by an average of ~0.072 g/l (Appendix C). The highest value came from the 'Fish Pond' sample while the lowest came from the 'Land Bridge' site (Figure 5.5).

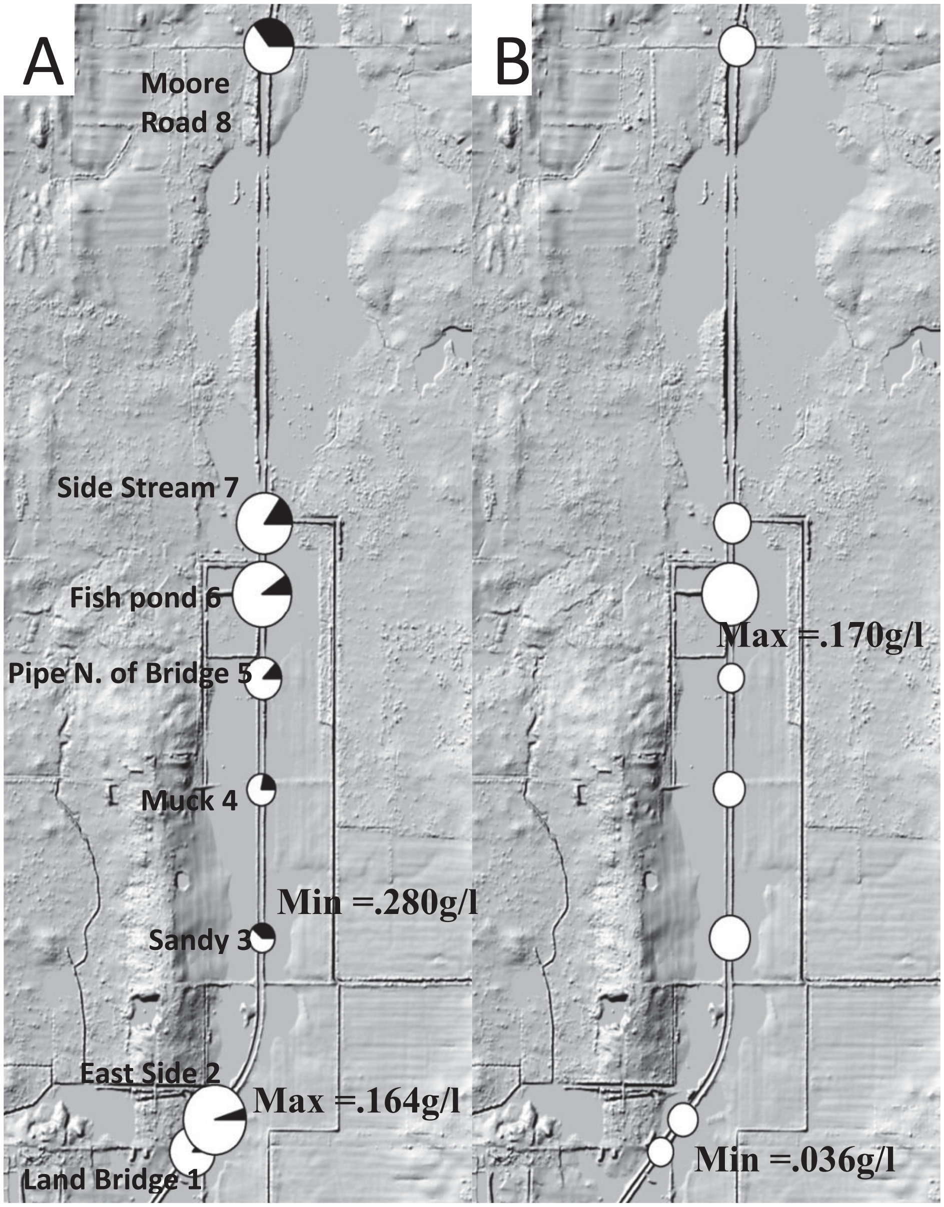

Figure 5.5. - Map showing pie graphs created from TS, TSS, and TVS data for the winter sampling event. The size of the pie chart is scaled to the total amount of sediment retrieved out of 1 ml of water. Map A portrays the dissolved solids (white) against the suspended solids (black), these comprise the TS. Map B are the volatile solids. Refer to Appendix A-C.

5.7 5th Sampling: April 6th 2014 (Spring Sample)

5.7.1 Sampling Conditions

The spring sampling was preceded by a two-day rain event that consisted of heavy showers. Sampling was performed between 10 A.M. to 1 P.M. during which time the temperature was around 37 ºF, leaving frost of the surrounding vegetation along the channel as well as in the fish ponds. Water depth was measured to be ~2.5 m. The 'Fish Pond' sample was taken from the inside the pipe due to no flow but standing water within the pipe. 'Pipe North of Bridge' was either submerged or had been swept away. All other sampling sites were re-visited as before (Appendix A-D).

5.7.2 TS Data

TS for the 8 sites had a range between ~0.106 g/l and ~0.654 g/l (Figure 5.5; Appendix A). The highest value was from the 'Muck' site while the lowest value came from the 'Pipe North of Bridge' site. The average was ~0.223 g/l for all sites over this sampling period (Appendix A).

5.7.3 TSS Data

TSS for the 8 sites ranged between ~0.012 g/l and ~0.510 g/l (Figure 5.5; Appendix B). The highest value was the 'Muck' site while the lowest was found at the 'Land Bridge' site. The average for the TSS was 0.081 g/l (Appendix B).

5.7.4 TVS Data

TVS ranged between ~0.096 g/l and ~0.294 g/l while all sites average ~0.174 g/l (Figure 5.5; Appendix C). The highest value came from the 'Muck' sample while the lowest came from the 'Pipe N. of Bridge' sample (Appendix C).

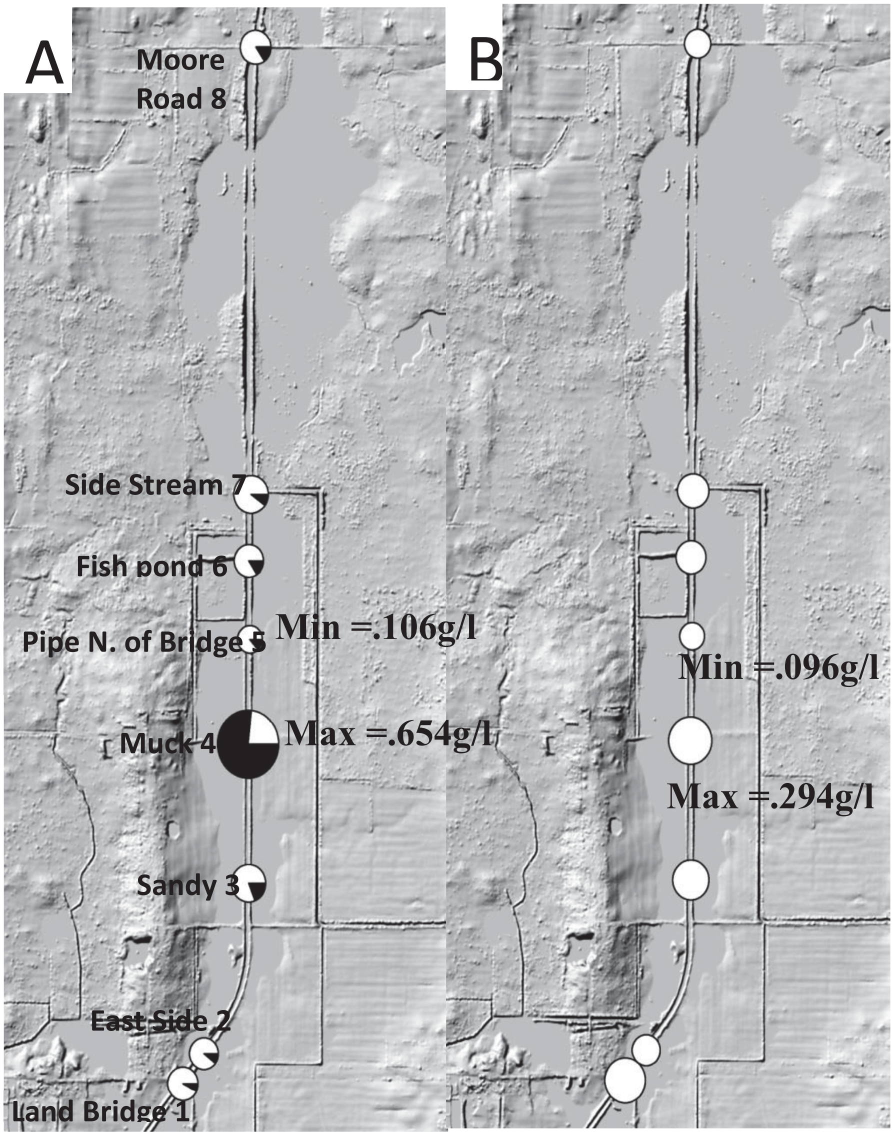

Figure 5.6 - Map showing pie graphs created from TS, TSS, and TVS data for the spring sampling event. The size of the pie chart is scaled to the total amount of sediment retrieved out of 1 ml of water. Map A portrays the dissolved solids (white) against the suspended solids (black,), these comprise the TS. Map B are the volatile solids. Refer to Appendix A-C.

CHAPTER 6

DISCUSSION

6.0 Insights into Seasonal Variances

This one-year sediment sampling study has produced data that shed some light onto what type of landscape and climate dynamics are at play at the Orwell site, which is very characteristic of the region as a whole. The following paragraphs attempt to explain variances in sediment loading between sites per sampling interval and the variance between sampling intervals (i.e. seasons). As only one seasonal representative dataset exists for fall, winter, and spring little can be said about variance from one event to the next within a given season and vegetative state. Two sampling events during the summer period provide some degree of comparison in this respect. Nonetheless, these data provide a general idea of how changes in vegetation cover (as a function of seasonality) may help drive variance in sediment input and how these variances are manifested along Snyder's Ditch and its variable land-use distribution along dip (Figure 6.0).

6.1. Variance between Sites

Base samples from all the sites reveal a seemingly uniform distribution of the total sediment load along Snyder's Ditch with very little noticeable variance (Figure 6.0). The corresponding sampling date was in May of 2013 during a period lacking prior rainfall. (Figure 6.0) shows the distribution of TS, TSS, and TVS for these baseline (i.e. low-flow) samples; it stands in stark contrast to data generated from samples from any of the other sampling days in that there is very little site-to-site variance recorded for this baseline event (Figures 5.0 – 5.6), attesting to the absence of point-source contributions during absent rainfall and low flow conditions.

Only the ‘Moore Road’ site (Site 8) data reveal highly elevated amounts of TSS (Figure 6.0). This is likely due to the site-specific conditions and retrieving the sample directly beneath the Moore Rd. Bridge, where water flows more quickly through a concrete constriction in the channel, causing turbulence and bottom-sediment re-suspension. While the surrounding terrain is characterized as a remnant wetland, which would be affiliated with little to no sediment contribution, values at this site may be elevated from this type of bottom re-suspension, which may account for the uniformly elevated values for TSS at this site, comparatively speaking (Figure 6.1).

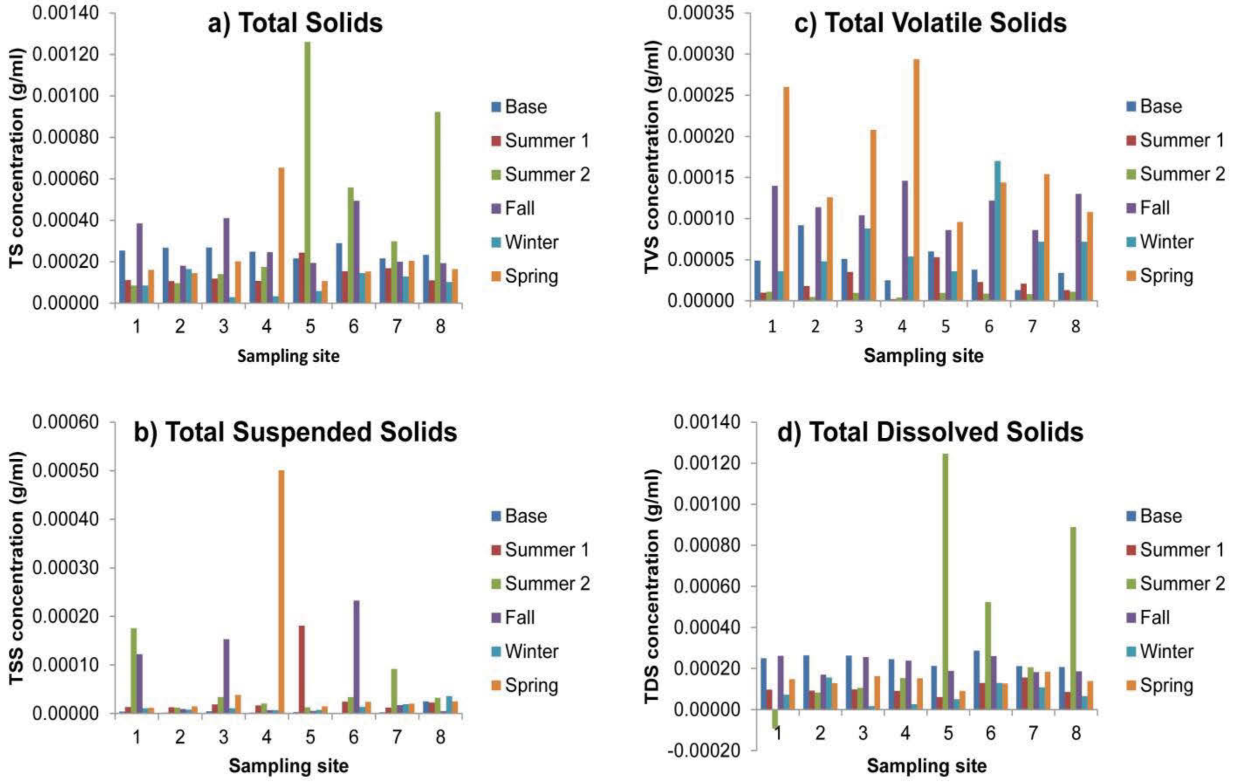

Figure 6.0 – Plots showing a) TS, b) TSS, c) TVS, and d) Total Dissolved Solids (TDS) for each sampling period for each of the 8 study sites. TDS was calculated as the difference between TS and TSS.

6.1.1 1st Sampling: July 12th, 2013 (Summer Sampling)

These samples were collected in July 2013 after a long rain period. It is very noticeable that the sediment trends differentiate from the base samples dramatically. The organic matter seems represent a uniform percentage (~9%) of the sediment load at all the sites except ‘Fish pond’, which had less organic matter content (~8%). The TSS and TVS are almost uniform in the ratios from site to site; however, site ‘Land bridge’, site 1, exhibits more TS due to higher amounts of TSS, a product of re-suspension at the bridge. The sampling site lies in front of a large culvert that connects the channel past the ‘Land Bridge’. In the summer the pipe is completely exposed and is a small distance above the channel water. This causes the water to flow into the stream while stirring/mixing it up, re-suspending bottom sediments. While this is the visible outlier, there are few small differences in the amount of sediment at the other sites.

6.1.2 2nd Sampling: August 9th, 2013 (Summer Sampling)

This sampling date was conducted in August of 2013. Relative to the Summer 1 samples, sediment concentrations in the Summer 2 samples are higher and more highly variable from site to site (Figures 5.2 and 5.3). The two sites that stand out are ‘Land Bridge’ and ‘Moore Road’; these two sites have uncharacteristically low percentages of TSS and TVS, suggesting that dissolved solids comprise the majority of the TS. Other anomalies are presented by the ‘Sandy’, whose TS concentration is defined largely by a very high TSS value (>50%). This is likely a function of high velocity of the outflow causing a turbulent sediment flow (Figure 4.2). A higher-than-average percentage of TSS at ‘Side Stream’ is likely due to contributions from the incoming tributary.

6.1.3 Difference in Summer Data

The two summer sampling dates reveal very different landscape responses to different types of rain event. The July sampling event was associated with a longer rain event than the August sampling date, while the latter was associated with heavier rain (Appendix D). Subsequently, more sediment (TS) was retrieved from the second summer sampling date (Figure 6.2), indicating that not differences in landcover, but the intensity of rain events is a strong driver of variance along the channel. The July rain event was long and steady; sediments may have been exhausted over the days of rain, leading to more uniform measurements across the area. August sampling took place during the ending of an intense rain event before the sediments may have been exhausted from the crust of the newly exposed soil.

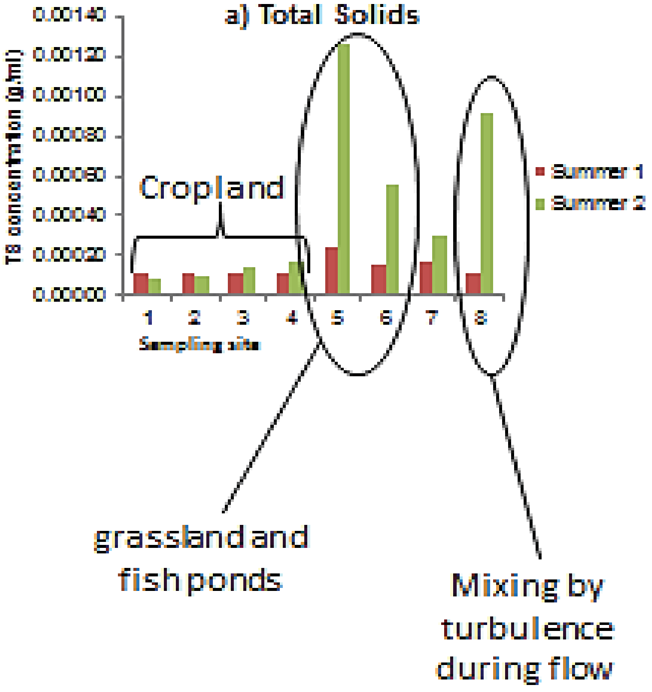

Figure 6.1 – Graph showing the differences between Summer 1 and Summer 2 data. The croplands have a lower amount of sediment collected compared to the grasslands, fish pond, and samples.

Differences in landcover type cannot be ignored in the discussion on the effects of different rain events as crop fields yielded less sediment than the grassland, fishpond, and woods overall and there was little difference between Summer 1 and Summer 2 rain events as was the case with the grasslands and fishponds (Figure 6.1 and 6.2). While it is unclear what the exact mechanisms or this variance are, it is clear that landcover type exhibits a strong control along with rainfall intensity on soil erosion and transport into Snyder's Ditch.

6.1.4 3rd Sampling: September 22nd, 2013(Fall Sampling)

Unlike the Summer 2 data the TS values for the fall sampling date show little variance between sites (Figure 5.4). The TSS values vary from site to site with high values associated with adjacent crop lands. This is also the portion of the channel that has a muddier channel bottom (Figure 5.0), suggesting that perhaps a portion of this could be due to re-suspension of channel sediments during this flow event or that suspended sediments tend not to leave this channel segment as readily.

TVS are elevated (>25%) compared to the Summer data (<10%), likely due to dead vegetation already making its way into the system. The elevated TS values for sites 'Sandy', 'Muck', and 'Pipe N. of Bridge' are explained by the TSS contributions; otherwise, all sites are very comparable in terms of TVS with the 'Muck' site having slightly elevated TVS values (close to 50%), likely due to the fact that this location has more vegetative cover during the summer which may translate to more dead organic matter being introduced here during the fall.

6.1.5 4th Sampling: February 21st, 2014 (Winter Sampling)

The winter samples are elevated in TVS content (>50% in most cases), attributed to the decay of vegetative matter and its contribution to the sediment budget. Noticeable are elevated values for the sampling points near crop fields and remnant wetland, which likely benefit from crops having been harvested for the year with organic matter left to deteriorate. Since these samples were taken after a major storm (Appendix D) and a large snowmelt event the dead matter had the opportunity to wash into the channel from adjacent fields.

6.1.6 5th Sampling: April 6th 2014 (Spring Sample)

Similar to the winter data, the spring data reveal that organic matter makes up the principal component of the TS values (>50%). The samples were taken in early spring when frost and ice were still prevalent to the area, but meltwaters and rain were able to create runoff conditions. The distribution of the different sediment fractions appear more or less uniform from site to site with the exception of site 'Muck', which has a disproportionate amount of TSS compared with the other sites; however, this is likely due to a sampling error based on notes taken and should not be considered in this analysis, leaving a more uniform distribution of sediment constituencies in water samples across all sites.

6.2 Variance between Seasons

6.2.1 Summer

The general trend in the summer months seems to depend on the rain event. The longer and steady rain lead to a lesser amount of sediment collected (Figure 5.1) while the heavier, rain for a shorter amount of time yielded more sediment (Figure 5.2). Higher amounts of TSS were yielded during intense rain during the end of the summer sampling due to disturbance of dry soil/ ground (Figure 6.0). As expected, the TVS yield is very low due to the summer being the growing season. The Summer 1 sampling date exhibits a higher volatile yield, which may be due to the excessive amount of precipitation that may have drowned out some of the surrounding flora.

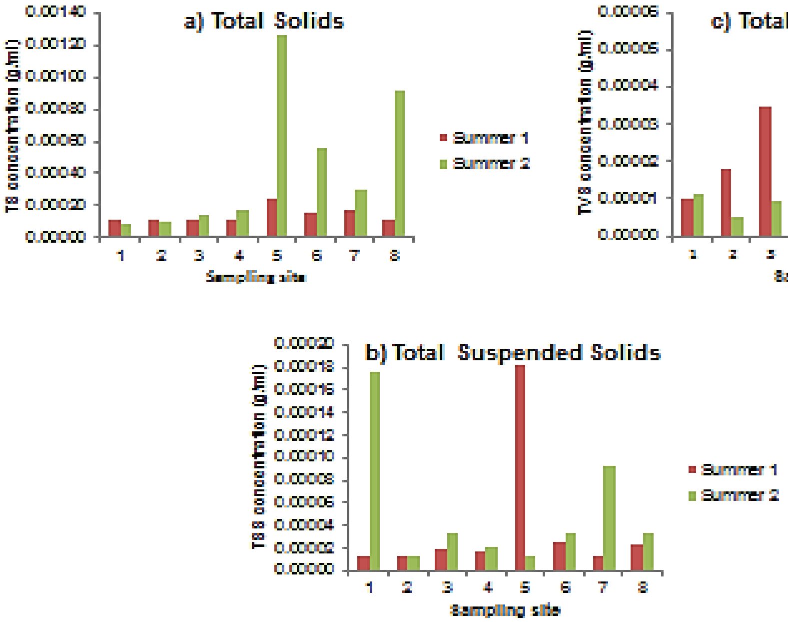

Figure 6.2 – Comparison of sedimentary data (a = TS, b = TSS, and c = TVS) from Summer 1 (shown in red) and Summer 2 (shown in green) sampling dates.

6.2.2 Fall

The samples collected from the sites were taken in early fall. The vegetation had not started to highly deteriorate yet. However, there is a distinction between the amounts of sediment between sites (Figures 5.3 and 6.1). There was more TSS along the field crops and wetland, likely due to sediments in fields being more heavily exposed and the nature of the outflow.

Figure 6.3 – Graphs of fall data (a = TS, b = TSS, and c = TVS).

6.2.3 Winter

The winter data appears to contain elevated TVS constituencies. This is due to the decomposition of the vegetation around the sites after the growing season. The least amount of sediment was collected in the winter months despite the increase in organic matter contributions, possibly because of ground freezing (Appendix A-C). The ground was frozen when samples were collect, as it tends to be for much of the winter months. The ‘Moore Road’ site showed an elevated percentage for TSS, again likely attributed so bottom sediment re-suspension.

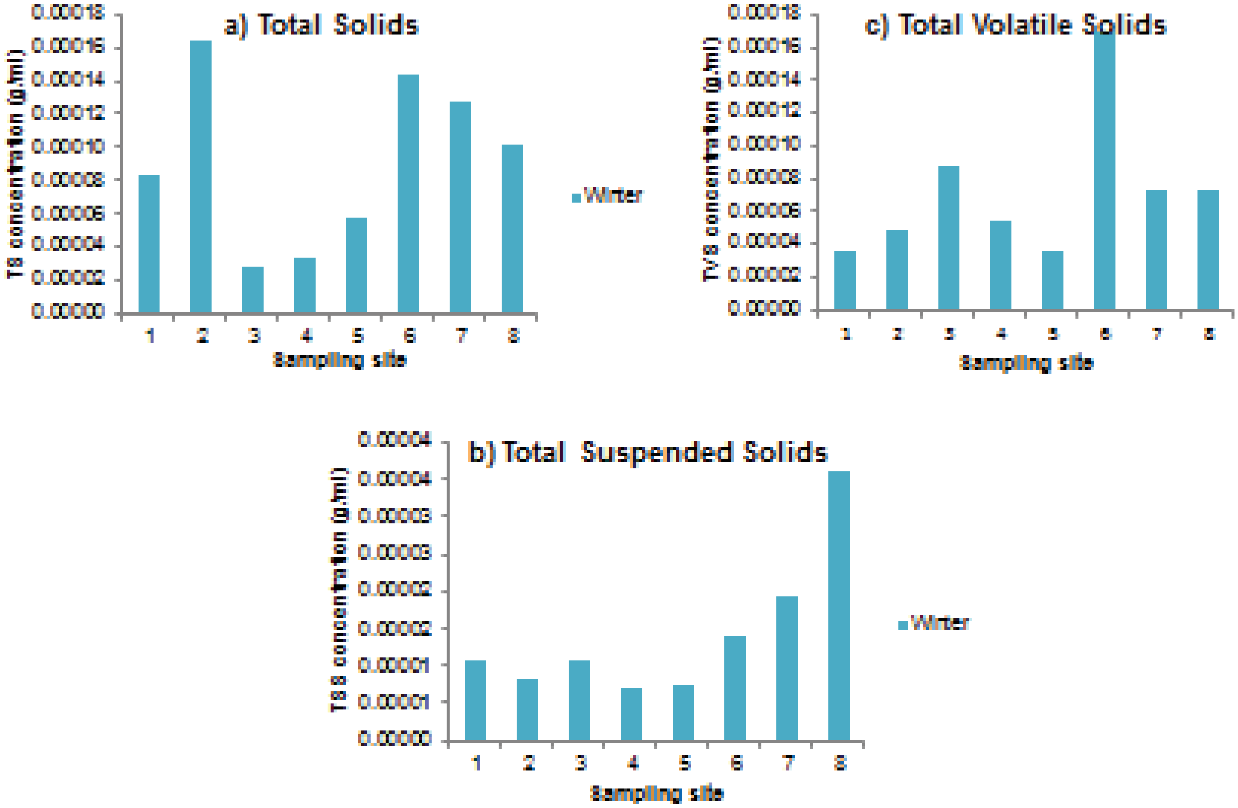

Figure 6.4 – Graphs of winter data (a = TS, b = TSS, and c = TVS).

6.2.4 Spring

The spring samples contained the highest amounts of volatile matter (Appendix C), which is a function of a high amount of dead organic debris that is being liberated from the landscape after being frozen throughout the heavy winter season. ‘Muck’ is an anomaly likely attributed to sampling/analysis error while the remainder of the samples vary little in sediment make-up (Figure 6.3).

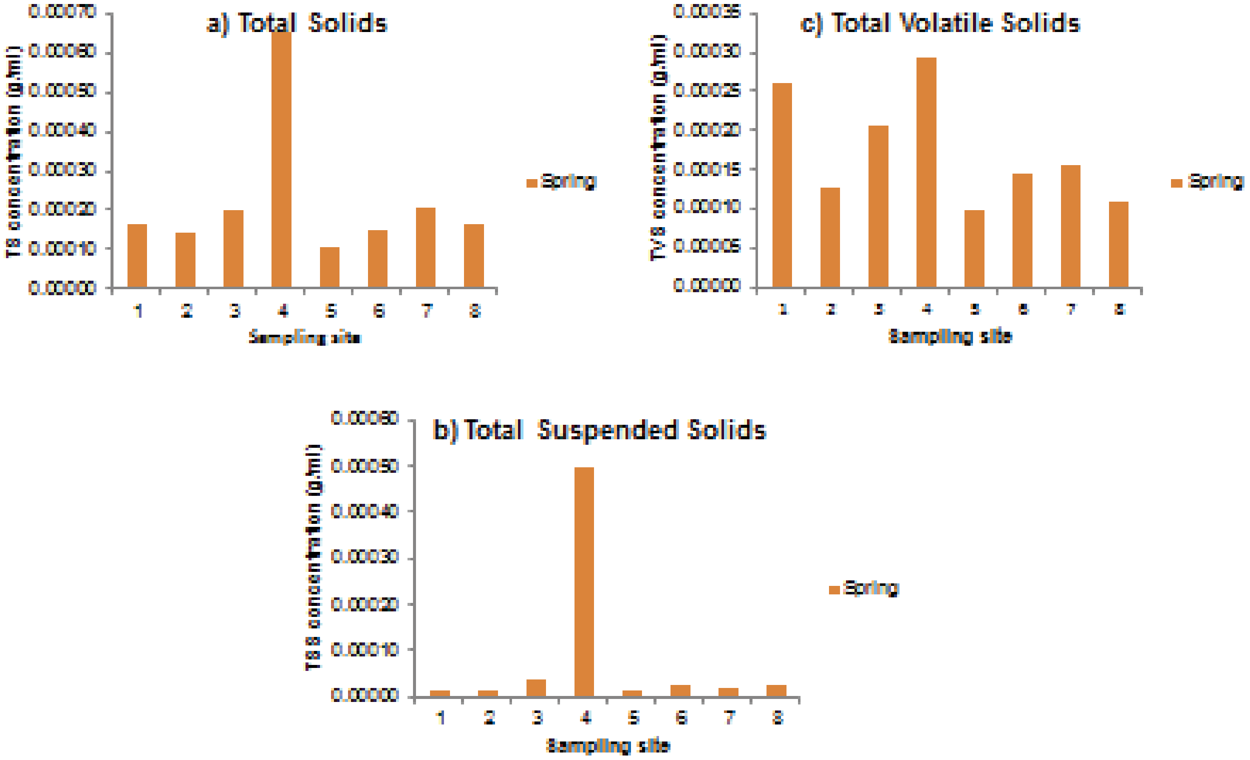

Figure 6.5 – Graphs of spring data (a = TS, b = TSS, and c = TVS).

Chapter 7

Conclusion

7.0 Conclusions and Recommendations

Snyder's Ditch is a channelized stream that has inflowing drains that contribute fluctuating sediment loads over the seasons. The goal of the research was to assess the landscape's connectivity and evaluate incoming sediment fluxes as a function of seasonality. Research questions were aimed to help focus sampling efforts and help illustrate sediment connectivity through the shallow agricultural landscape. The data suggest a higher degree of connectivity than simple soil-erosion models such as the USLE would suggest; this is largely due to the presence of tile drains that are not accounted for in surficial soil-erosion modeling. The USLE model (Figure 2.3) suggests that there should be very little variance from site to site due to low gradient and comparable soil content; areas modeled to be higher in soil erosion include the farm fields while areas modeled to be lesser sediment contributors include the fish farms and grasslands; this study shows that the latter are actually significant contributors of sediments, most notably organic sediments. This connectivity would not be possible were it not for the tile drains and pipes that funnel these sediments into Snyder's Ditch directly. Models must account for this heightened degree of landscape connectivity and more research is needed to establish the full extent of the effects. It must be stated that many of the tile drains and pipes that once facilitated heightened sediment transport have collapsed. It is clear that modeling soil erosion becomes increasingly complex in highly modified landscapes given these highly site-specific effects on connectivity.

The data here show there are many sediment point sources along the stream which can be linked to specific sub-fields that are easily delineated. However, a spatial correlation between landcover type and sediment influx to Snyder's Ditch was not resolved in great detail. The southern half of the study site is mostly covered by row crops while the northern section is mostly characterized by pastureland, fish ponds filled in with vegetation, and woodland. This project has yielded no distinct evidence that proves cultivated landcover promotes higher sediment loss than the other landcover type over long time spans. However, differences were resolved for individual events that are linked to seasonal variations. It was noticed, for example, that row crops contributed more sediment, largely TSS, during dry months with fast and hard rain, which is discussed in the literature (Singh et al., 2007). Likewise, land cover types that are not agricultural tend to provide more TVS contributions during certain times of the year (i.e. winter and spring) than croplands.

The variance in sediment flux to the ditch over time is less conclusive than needed for model calibration as the study lacks continuous data and can thus not address sediment-exhaustion effects, for example; however, comparing similar rain events and sediment concentrations along the ditch over the seasons provides some clues regarding the seasonal dynamics of the area. Data from both summer sampling events illustrate this point quite well as the shorter, heavier rain event (Summer 2) was associated with a much higher sediment load than the following event (Summer 1).

More events need to be evaluated at higher temporal resolutions to provide a better understanding of these dynamics. The sediment data also resolve other trends that relate to seasonality. Warmer months are associated with more sediment loading than the winter months; this is because, while rain events and snowmelt do provide suitable surface runoff conditions, the ground in winter time is still largely frozen and sediment particles are not eroded as readily due to the inability for water to infiltrate into the ground (Bogen & Bonsnes, 2003). Associated with this effect is also the fate of organic material, which is more heavily enriched in winter and spring as vegetation dies and is carried off the terrain. The data show this as an increase in TVS in samples during the winter and spring despite decreased TS. Higher amounts of sediments were sampled in the drier months.

GIS based models can be very useful for conceptualizing landscape connectivity. The GIS-based maps created to estimate soil loss for the Snyder's Ditch are highly inaccurate. The USLE model estimates a 0% soil loss along the channel; furthermore, models of landscape connectivity cannot account for subterranean links established between the agricultural plots and the ditch through tile drains. While the erosion map overlooks soil contributions from the adjacent tile-drained farmland given low surface gradient, it is unknown exactly by how much this is. More detailed monitoring of sediment movement through the channel over a variety of rain events and for all seasons would aid in helping estimate sediment flux numerically, providing a comparison for USLE model estimates.

REFERENCES

American Public Health Association, American Water Works Association, Water EnvironmentFederation. 1998.Standard Methods for the Examination of Water and Wastewater.Washington (DC): American Public Health Association.

Basson, G., 2010. ICOLD Bulletin: Sedimentation and sustainable use of reservoirs and river systems. ICOLD Sedimentation Committee.

Benton M., Harper D. 2009. Introduction to pale biology and the Fossil Record. Singapore:Markono Print Media.

Blaszczynski, J., 2001. Regional sheet and rill soil erosion prediction with the Revised Universal Soil Loss Equation (RUSLE) – GIS interface. Resource Notes 46.

Bogen J. Bonsnes T. 2003. Erosion and sediment transportation in high artic rivers, Svalbard.Polar Research. 22 (2): 175-189.

Booker A. 1987. Sinuosity os artificially straightened stream channels. Environmental Geology Water Sciences. 10 (1): 33- 41.

Bracken L, Croke J. 2007. The concept pf hydrological connectivity and its contribution tounderstanding runoff- dominated geographic systems. Hydrologic Processes. 21: 1749 1763.

Crowder, B.M., 1987. Economic costs of reservoir sedimentation: A regional approach to estimating cropland erosion damage. Journal of Soil and Water Conservation 42, 194 197.

Dabral, P.P., Baithuri, N., Pandey, A., 2008. Soil erosion assessment in a hilly catchment of north eastern India using USLE, GIS and remote sensing. Water Resource Management 22, 1783-1798.

Erdogan, E.H., Erpul, G., Bayramin, I., 2007. Use of USLE/GIS methodology for predicting soil loss in a semiarid agricultural watershed. Environmental Monitoring and Assessment 131, 153-161.

Deasy C, Brazier R, Heathwaite A, Hodgekinson R. 2009. Pathways of runoff and sedimenttransfer in small agricultural catchments. Hydrological Processes. 23: 1349 1358.

De Vente, j., Poesen, M., Arabhkedri, M., Verstraeten, G., 2007. The sediment delivery problem revisited, Progress in Physical Geography 31, 155-178.

Gascuel- Odoux C, Cros- Cayot S, Durand R. 1996. Spatial variations of sheet flow and sediment transport on an agriculture field. Earth Surface Processes and Landforms.21: 843- 851.

Geo Facts. Ohio Division of Natural Resources: Division of Geological Survey. [Internet].2001. [cited 2012 Nov 17]. Available from: www.dnr.state.oh.us.

Hook R, Baird D. 1988. An overview of the upper Carboniferous fossil deposits in Linton,Ohio. Ohio J Science. 88 (1): 55-60.

Houben P, Wunderlich J, Schrott. 2009. Climate and long- term human impact on sedimentfluxes in watershed systems. Geomorphology. 108: 1-7.

Hrissanthou V. 2005. Estimate of sediment yield in a basin without sediment data. Catena. 64:333-347.

Kuhnle R. Simon A. 2000. Evaluation of Sediment Transport Data for Clean Sediments TMDLs. National Sedimentation Laboratory.

Laflen, J. M., Elliot, W. J., Simanton, J. R., Holzhey, C. S., & Kohl, K. D. (1991). WEPP: Soil erodibility experiments for rangeland and cropland soils. Journal of Soil and Water Conservation, 46(1), 39-44.

Lawrence J . 1905. History of Ohio from the glacial period to the present. Union Publishing Co.Columbus, Ohio.

Lesschen J, Schoorl J, Cammeraat L. 2009. Modelling runoff and erosion for a semi aridcatchment using a multi- scale approach based on hydrological connectivity.Geomorphology. 109: 174- 183.

Lopez F. Garcia M. 1998. Open-channel flow through simulated equitation suspended sediments transport modeling. Water Resources Research. 34 (9): 2341-2352.

Lou W, Sands G, Youssef M, Strock J, Song L, Canelon D. 2010. Modeling the impact ofalternative drainage practices in the northern Corn- belt with DRAINMOD-NII. Agricultural Water Management. 97: 389-398.

Lufafa, A., Tenywa, M.M., Isabirye, M., Majaliwa, M.J.G., Woomer, P.L., 2003. Prediction of soil erosion in a Lake Victoria basin catchment using a GIS-based Universal Soil Loss model. Agricultural Systems 76, 883-894.

Macrae M, English M, Stone S. 2007. Intra-annual variability in the contribution of tile drains tobasin discharge and phosphorous export in a first- order agricultural catchment. Agricultural Water Management. 92: 171-182.

Marque M, Ramon B, Jimenez L, Perez- Rodriguez R. 2007. Effects of vegal cover on runoffand soil erosion under light intensity events. Rainfall simulation over USLE plots.Science of the Total Environment. 378: 161-165.

Matisoff G, Bonniwell E, Whiting P. 2002. Soil erosion and sediment sources in an Ohio watershed using beryllium-7, celsium-137, and lead-210. J Environmental Quality. 31:54-61.

Matisoff G, Bonniwell E, Whiting P. 2002. Radionuclides as indicators of sediment transport in agricultural watersheds that drain to Lake Erie. J Environmental Quality. 31: 62- 71.

Michael A, Schmidt J, Snke W, Deutschlander Th, Malitz G. 2005. Impact of expected increasein precipitation intensities on soil loss- results of comparative model simulations. Catena.61: 155- 164.

Nearing M. 1997. Why soil erosion models over predict small soil losses and under predict largesoil losses. Catena. 32: 15-22.

Oeurng C, Sauvage S, Sanchez-Perez J. 2010. Dynamics of suspended sediment transport and yield in a large agricultural catchment, southwest France. 35: 1289- 1301.

Ozcan, A.U., Erpul, G., Basaran, M., Erdogan, H.E., 2008. Use of USLE/GIS technology integrated with geostatistics to assess soil erosion risk in different land uses of Indagi Mountain Pass, Cankiri, Turkey. Environmental Geology 53, 1731-1741.

Palmieri, A. Shah, F., Dinar, A., 2001. Economics of reservoir sedimentation and sustainable management of dams. Journal of Environmental Management 61, 149-163.

Pandey, A., Chowdary, V.M., Mal, B.C., 2007. Identification of critical erosion prone areas in the small agricultural watershed using USLE, GIS, and remote sensing. Water Resource Management 21, 729-746.

Parbhakar- Fox A. Edraki M. Walters S. Bradshaw D. 2011. Development of textual indexfor the prediction of acid rock drainage. Mineral Engineering. 24: 1277-1287.

Pennsylvanian Record. Ohio History Central. [Internet]. 2007. [cited 2012 Nov 17]. Available from: www.ohiohistory/central.org.

Renschler C, Harbor J. 2002. Soil erosion assessment tools from point to regional scales- the roleof geomorphologists in land management research and implementation. Geomorphology.47: 189- 209.

Sidorchuk, A., Walling, D., & Wasson, R. (2003). A LUCIFS strategy: modelling the sediment budgets of fluvial systems. In Long Term Hillslope and Fluvial System Modelling (pp. 19-35). Springer Berlin Heidelberg.

Singn R, Helmers M, Qi Z. 2006. Calibration and validation of DRAINMOD to desigsubsurface drainage for Iowa's tile landscapes. Agricultural Water Management. 85: 221232.

Singn R, Helmers M, Crumpton W, Lemke D. 2007. Predicting effects of drainage water management in Iowa's subsurface drained landscapes. Agricultural Water Management. 92: 162-170.

Sivertun, A., Prange, L., 2003. Non-point source critical area analysis in the Gisselö watershed using GIS. Environmental Modeling and Software 18, 887-898.

Skaggs, R. W. (1982). Field evaluation of a water management simulation model [DRAINMOD; North Carolina]. Transactions of the ASAE [American Society of Agricultural Engineers](USA).

Stone M, Krishnappan B. 1997. Trasport characteristics of tile- drained sediments from anagricultural watershed. Water,Air, Soil Pollution. 99: 89- 103.

Summer W. Walling D. 2002. Modeling erosion, sediment transport and sediment yield. International Hydrological Programme.

Waggoner B. 1996. The Carboniferous Period. University of California Museum of Paleontology. [Internet]. [cited 2013 Feb 16]. Available from: www.ucmp.berkley.edu/carboniferous/carboniferous.php.

Walling, D.E., 1983. The sediment delivery problem. Journal of Hydrology 65, 209-237.

Walling D, Collins A. 2008. The catchment sediment budget as a management tool.Environmental Science and Policy. 11: 136- 143.

Walling, D. E., & Fang, D. (2003). Recent trends in the suspended sediment loads of the world's rivers. Global and Planetary Change, 39(1), 111-126.

Wang, Z., Hu, C., 2009. Strategies for managing reservoir sedimentation. International Journal of Sediment Research 24, 369-384.

Wischmeier, W. H., Johnson, C. B., & Cross, B. V. (1971). Soil erodibility nomograph for farmland and construction sites.

Wischmeier, W.H., Smith, D.D., 1978. Predicting rainfall erosion losses – a guide to conservation planning. USDA Agricultural Handbook 537, 58 pp.

Zimmerman, J. K., Vondracek, B., & Westra, J. (2003). Agricultural land use effects on sediment loading and fish assemblages in two Minnesota (USA) watersheds. Environmental Management, *32*(1), 93-105.

APPENDIX A
Total solid data for all sampling locations

Samples	crucible weight (g)	crucible weight after oven (g)	Total solid weight (g)	grams of sediment per l water:
Sandy 1	67.421	67.4338	0.0128	0.256
Sandy 2	68.2441	68.2567	0.0126	0.252
East side 1	71.9182	71.9324	0.0142	0.284
East side 2	58.4476	58.4611	0.0125	0.250
N. of bridge 1	66.3472	66.36	0.0128	0.256
N. of bridge 2	60.5646	60.5786	0.014	0.280
Fish Pond 1	60.5474	60.5622	0.0148	0.296
Fish Pond 2	24.1465	24.1555	0.009	0.180
Land bridge 1	36.2083	36.2182	0.0099	0.198
Land Bridge 2	37.5918	37.6035	0.0117	0.234
Muck 1	36.8464	36.861	0.0146	0.292
Muck 2	38.5212	38.5355	0.0143	0.286
Side Stream 1	40.7232	40.7338	0.0106	0.212
Side Stream 2	24.7268	24.7377	0.0109	0.218
Moore Road 1	33.5701	33.5804	0.0103	0.206
Moore Road 2	33.7764	33.7894	0.013	0.260

TS data for May 28, 2013

Samples	**Crucible weight before (g)**	**Crucible weight after (g)**	**Total Solid weight (g)**	**Grams per l of water**
Sandy 1	64.789	64.795	0.006	0.120
Sandy 2	68.1304	68.1355	0.0051	0.102
East side 1	64.2069	64.2122	0.0053	0.106
East side 2	65.5944	65.5997	0.0053	0.106
N. of bridge 1	66.556	66.5618	0.0058	0.116
N. of bridge 2	71.9228	71.9288	0.006	0.120
Fish Pond 1	60.5525	60.5577	0.0052	0.104
Fish Pond 2	64.907	64.9121	0.0051	0.102
Land bridge 1	67.651	67.662	0.011	0.220
Land Bridge 2	66.3501	66.3634	0.0133	0.266
Muck 1	62.8064	62.8128	0.0064	0.128
Muck 2	50.1287	50.1377	0.009	0.180
Side Stream 1	49.6164	49.6252	0.0088	0.176
Side Stream 2	68.2461	68.2542	0.0081	0.162
Moore Road 1	70.3022	70.3076	0.0054	0.108
Moore Road 2	64.29	64.2956	0.0056	0.112

TS for July 12, 2013

Samples	Crucible weight before (g)	Crucible weight after oven (g)	Total solid weight (g)	Grams per l of water
Sandy 1	21.5395	21.5371	0.0024	0.096
Sandy 2	35.9481	35.9463	0.0018	0.072
East side 1	36.2190	36.2168	0.0022	0.088
East side 2	33.5806	33.5780	0.0026	0.104
N. of bridge 1	24.7397	24.7363	0.0034	0.136
N. of bridge 2	36.9500	36.9464	0.0036	0.144
Fish Pond 1	23.9642	23.9614	0.0028	0.112
Fish Pond 2	24.8311	24.8243	0.0068	0.272
Land bridge 1	38.5806	38.5316	0.0490	1.960
Land Bridge2	37.6146	37.6006	0.0140	0.560
Muck 1	24.1735	24.1551	0.0184	0.736
Muck 2	33.7959	33.7864	0.0095	0.380
Side Stream 1	34.8534	34.8452	0.0082	0.328
Side Stream 2	34.2366	34.2299	0.0067	0.268
Moore Road1	36.8873	36.8563	0.0310	1.240
Moore Road2	40.7488	40.7337	0.0151	0.604

TS for August 9, 2013

Samples	**Crucible weight before 105C (g)**	**After oven (g)**	**TS (g)**	**Grams per l of water**
Sandy 1	25.0395	25.0404	0.0009	0.036
Sandy 2	36.7955	36.7988	0.0033	0.132
East Side 1	37.6479	37.651	0.0031	0.124
East Side 2	26.8937	26.8988	0.0051	0.204
North of Bridge 1	43.4979	43.498	0.0001	0.004
North of Bridge 2	40.9994	41.0007	0.0013	0.052
Fish Pond 1	37.1571	37.1581	0.001	0.040
Fish pond 2	33.9809	33.9817	0.0008	0.032
Land Bridge 1	36.2135	36.2145	0.001	0.040
Land Bridge 2	40.7281	40.7300	0.0019	0.076
Muck 1	24.5379	24.5415	0.0035	0.140
Muck 2	24.5984	24.6021	0.0037	0.148
Side Stream 1	42.8513	42.8549	0.0036	0.144
Side Stream 2	42.1782	42.1810	0.0028	0.112
Moore Road 1	34.2211	34.2242	0.0031	0.124
Moore Road 2	33.575	33.5770	0.002	0.080

TS for February 21, 2014

Samples	Crucible weight before 105 C oven (g)	Crucible weight after oven (g)	TS (g)	Grams per l of water
Sandy 1	36.2142	36.2239	0.0097	0.388
Sandy 2	33.5758	33.5853	0.0095	0.380
East side 1	37.5974	37.6022	0.0048	0.192
East side 2	24.8215	24.8257	0.0042	0.168
N. of bridge 1	21.5249	21.5354	0.0105	0.420
N. of bridge 2	23.9596	23.9696	0.0100	0.400
Fish Pond 1	24.5271	24.5403	0.0132	0.528
Fish Pond2	34.2234	34.2349	0.0115	0.460
Land bridge 1	34.8375	34.8431	0.0056	0.224
Land Bridge 2	38.5288	38.5329	0.0041	0.164
Muck 1	35.9367	35.9405	0.0038	0.152
Muck 2	24.7323	24.7367	0.0044	0.176
Side Stream 1	25.6594	25.6647	0.0053	0.212
Side Stream 2	24.9684	24.4731	0.0047	0.188
Moore Road 1	24.1516	24.1567	0.0051	0.204
Moore Road 2	40.7303	40.7348	0.0045	0.180

TS for September 22, 2013

Samples	**Crucible weight before oven (g)**	**Weight After (g)**	**Total Solids (g)**	**Grams per l of water**
Sandy 1	64.2881	64.2924	0.0043	0.172
Sandy 2	34.1804	34.1841	0.0037	0.148
East Side 1	34.5081	34.5117	0.0036	0.144
East Side 2	42.2187	42.2223	0.0036	0.144
North of Bridge 1	37.1738	37.1773	0.0035	0.014
North of Bridge 2	28.6301	28.6367	0.0066	0.264
Muck 1	38.0401	38.0593	0.0192	0.768
Muck 2	39.6418	39.6666	0.0248	0.992
Land Bridge 1	26.7826	26.7848	0.0022	0.088
Land Bridge 2	41.5432	41.5463	0.0031	0.124
Fish Pond 1	28.3344	28.3388	0.0044	0.176
Fish Pond 2	27.6993	27.7025	0.0032	0.128
Side Stream 1	64.9058	64.9111	0.0053	0.212
Side Stream 2	60.5654	60.5703	0.0049	0.196
Moore Road 1	26.4954	26.4995	0.0041	0.164
Moore Road 2	26.5628	26.5669	0.0041	0.164

TS for April 6, 2014

APPENDIX B

Suspended Solid data for all sampling locations.

Samples	weight of filter paper before (g)	weight after bake at 105c (g)	TSS (g)	Grams per l of water
Sandy 1	0.1200	0.1211	0.0011	0.004
Sandy 2	0.1200	0.1214	0.0014	0.005
East side 1	0.1181	0.1184	0.0003	0.001
East side 2	0.1199	0.1209	0.001	0.003
N. of bridge 1	0.1172	0.1187	0.0015	0.005
N. of bridge 2	0.1184	0.1197	0.0013	0.004
Fish Pond 1	0.1185	0.1193	0.0008	0.003
Fish Pond 2	0.1164	0.117	0.0006	0.002
Land bridge 1	0.1185	0.1197	0.0012	0.004
Land Bridge 2	0.1188	0.1196	0.0008	0.003
Muck 1	0.1173	0.1178	0.0005	0.002
Muck 2	0.1174	0.1178	0.0004	0.001
Side Stream 1	0.1187	0.1195	0.0008	0.003
Side Stream 2	0.1240	0.1249	0.0009	0.003
Moore Road 1	0.1151	0.1222	0.0071	0.024
Moore Road 2	0.1176	0.1256	0.008	0.027

TSS data for May 28, 2013

Samples	**Weight of filter paper before(g)**	**Weight of filter paper after oven (g)**	**TSS (g)**	**Grams per l of water**
Sandy 1	0.1188	0.1225	0.0037	0.012
Sandy 2	0.1194	0.1238	0.0044	0.015
East side 1	0.1224	0.1264	0.004	0.013
East side 2	0.12	0.1239	0.0039	0.013
N. of bridge 1	0.1229	0.1278	0.0049	0.016
N. of bridge 2	0.1227	0.1292	0.0065	0.022
Fish Pond 1	0.1188	0.1229	0.0041	0.014
Fish Pond 2	0.1188	0.1249	0.0061	0.020
Land bridge 1	0.1184	0.1694	0.051	0.170
Land Bridge 2	0.1188	0.1766	0.0578	0.193
Muck 1	0.1193	0.1272	0.0079	0.026
Muck 2	0.1197	0.1267	0.007	0.023
Side Stream 1	0.122	0.1258	0.0038	0.013
Side Stream 2	0.1226	0.1262	0.0036	0.012
Moore Road 1	0.1174	0.1219	0.0045	0.015
Moore Road 2	0.1174	0.1265	0.0091	0.030

TSS for July 12, 2013

Samples	**Weight before oven (g)**	**Weight after filter and oven (g)**	**TSS (g)**	**Grams per l of water**
Sandy 1 (p2536)	0.1189	0.2028	0.0839	0.279
Sandy 2 (p2535)	0.1219	0.1433	0.0214	0.071
East side 1 (p2538)	0.1228	0.1268	0.0040	0.013
East side 2 (p2537)	0.1193	0.1229	0.0036	0.012
N. of bridge 1 (p2299)	0.1180	0.1299	0.0119	0.040
N. of bridge 2 (p2298)	0.1177	0.1261	0.0084	0.028
Fish Pond 1 (p2542)	0.1233	0.1302	0.0069	0.023
Fish Pond 2 (p2541)	0.1190	0.1245	0.0055	0.018
Land bridge 1 (p2544)	0.1245	0.1286	0.0041	0.014
Land Bridge 2 (p2543)	0.1225	0.1263	0.0038	0.013
Muck 1 (p2540)	0.1215	0.1328	0.0113	0.038
Muck 2 (p2539)	0.1229	0.1321	0.0092	0.031
Side Stream 1 (p2534)	0.1187	0.1436	0.0249	0.083
Side Stream 2 (p2297)	0.1182	0.1485	0.0303	0.101
Moore Road 1 (p2533)	0.1226	0.1314	0.0088	0.029
Moore Road 2 (p2545)	0.1211	0.1317	0.0106	0.035

TSS for August 9, 2013

Samples	Weight of filter paper before (g)	Weight after 105 C oven (g)	TSS (g)	Grams per l of water
Sandy 1 (p2511)	0.1169	0.1527	0.0358	0.119
Sandy 2 (p2510)	0.1240	0.1616	0.0376	0.125
East side 1 (p2509)	0.1240	0.1271	0.0036	0.012
East side 2 (p2508)	0.1169	0.1191	0.0022	0.007
N. of bridge 1 (p2506)	0.1188	0.1493	0.0305	0.203
N. of bridge 2 (p2507)	0.1234	0.1389	0.0155	0.103
Muck 1 (p2498)	0.1226	0.1247	0.0021	0.007
Muck 2 (p42499)	0.1194	0.1216	0.0022	0.007
Land bridge 1 (p2502)	0.1234	0.1247	0.0013	0.004
Land Bridge 2 (p2503)	0.1197	0.1218	0.0021	0.007
Fish Pond 1 (p2504)	0.1230	0.1729	0.0499	0.333
Fish Pond2 (p2505)	0.1235	0.1433	0.0199	0.133
Side Stream 1 (p2496)	0.1181	0.1236	0.0055	0.018
Side Stream 2 (p2497)	0.1163	0.1211	0.0048	0.016
Moore Road 1 (p2500)	0.1237	0.1252	0.0015	0.005
Moore Road 2 (p2501)	0.1196	0.1212	0.0016	0.005

TSS for September 22, 2013

Samples	**Filter Weight Before (g)**	**Filter Weight After (g)**	**TSS (g)**	**Grams per l of water**
Sandy 1	0.1241	0.1265	0.0024	0.008
Sandy 2	0.123	0.1271	0.0041	0.014
East Side 1	0.1237	0.1259	0.0022	0.007
East Side 2	0.1244	0.1271	0.0027	0.009
North of Bridge 1	0.1153	0.1193	0.004	0.013
North of Bridge 2	0.1191	0.1216	0.0025	0.008
Fish Pond 1	0.1263	0.1282	0.0019	0.006
Fish pond 2	0.1254	0.1278	0.0024	0.008
Land Bridge 1	0.1243	0.1269	0.0026	0.009
Land Bridge 2	0.125	0.1271	0.0019	0.006
Muck 1	0.1228	0.1273	0.0045	0.015
Muck 2	0.1202	0.124	0.0038	0.013
Side Stream 1	0.1254	0.1314	0.006	0.020
Side Stream 2	0.1191	0.1248	0.0057	0.019
Moore Road 1	0.119	0.1299	0.0109	0.036
Moore Road 2	0.1202	0.1309	0.0107	0.036

TSS for February 21, 2014

Samples	Filter Weight before (g)	Filter Weight After (g)	Suspended Solids (g)	Grams per l of water
Sandy 1	0.1239	0.1274	0.0035	0.010
Sandy 2	0.1245	0.1282	0.0037	0.010
East Side 1	0.1236	0.1271	0.0035	0.010
East Side 2	0.1236	0.1291	0.0055	0.020
North of Bridge 1	0.1244	0.1391	0.0147	0.050
North of Bridge 2	0.1266	0.1351	0.0085	0.030
Muck 1	0.1241	0.1995	0.0754	0.380
Muck 2	0.1258	0.2507	0.1249	0.620
Land Bridge 1	0.1252	0.1301	0.0049	0.020
Land Bridge 2	0.1256	0.1295	0.0039	0.010
Fish Pond 1	0.1255	0.1328	0.0073	0.020
Fish Pond 2	0.1264	0.1336	0.0072	0.020
Side Stream 1	0.1249	0.1298	0.0049	0.020
Side Stream 2	0.1254	0.1327	0.0073	0.020
Moore Road 1	0.1234	0.1323	0.0089	0.030
Moore Road 2	0.1255	0.1317	0.0062	0.020

TSS for April 6, 2014

APPENDIX C

Volatile Solid data for all sampling locations.

Samples	Weight before 550c oven (g)	weight after 550c oven (g)	TVS (g)	Grams per l of water
Sandy 1	67.4338	67.4313	0.0025	0.050
Sandy 2	68.2567	68.2543	0.0024	0.048
East side 1	71.9324	71.9282	0.0042	0.084
East side 2	58.4611	58.4561	0.005	0.100
N. of bridge 1	66.36	66.3574	0.0026	0.052
N. of bridge 2	60.5786	60.5761	0.0025	0.050
Fish Pond 1	60.5622	60.5602	0.002	0.040
Fish Pond 2	24.1555	24.155	0.0005	0.010
Land bridge 1	36.2182	36.216	0.0022	0.044
Land Bridge 2	37.6035	37.5997	0.0038	0.076
Muck 1	36.861	36.8594	0.0016	0.032
Muck 2	38.5355	38.5333	0.0022	0.044
Side Stream 1	40.7338	40.7331	0.0007	0.014
Side Stream 2	24.7377	24.7371	0.0006	0.012
Moore Road 1	33.5804	33.5797	0.0007	0.014
Moore Road 2	33.7894	33.7867	0.0027	0.054

TVS data for May 28, 2013

Samples	Weight before 550c oven (g)	Weight after oven (g)	TVS (g)	Grams per l of water
Sandy 1	64.795	64.7949	0.0001	0.002
Sandy 2	68.1355	68.1346	0.0009	0.018
East side 1	64.2122	64.2110	0.0012	0.024
East side 2	65.5997	65.5991	0.0006	0.012
N. of bridge 1	66.5618	66.5607	0.0011	0.022
N. of bridge 2	71.9288	71.9264	0.0024	0.048
Fish Pond 1	60.5577	60.5576	0.0001	0.002
Fish Pond 2	64.9121	64.9120	0.0001	0.002
Land bridge 1	67.662	67.6595	0.0025	0.050
Land Bridge 2	66.3634	66.3606	0.0028	0.056
Muck 1	62.8128	62.8119	0.0009	0.018
Muck 2	50.1377	50.1363	0.0014	0.028
Side Stream 1	49.6252	49.6232	0.0020	0.040
Side Stream 2	68.2542	68.2541	0.0001	0.002
Moore Road 1	70.3076	70.3074	0.0002	0.004
Moore Road 2	64.2956	64.2945	0.0011	0.022

TVS for July 12, 2013

Samples	Weight before oven (g)	Weight after 550 C oven (g)	TVS (g)	Grams per l of water
Sandy 1	21.5371	21.5340	0.0031	0.010
Sandy 2	35.9463	35.9438	0.0035	0.012
East side 1	36.2168	36.2153	0.0015	0.005
East side 2	33.5780	33.5767	0.0013	0.004
N. of bridge 1	24.7363	24.7343	0.0020	0.007
N. of bridge 2	36.9464	36.9427	0.0037	0.012
Fish Pond 1	23.9614	23.9604	0.0010	0.003
Fish Pond 2	24.8243	24.8229	0.0014	0.005
Land bridge 1	38.5316	38.5274	0.0042	0.014
Land Bridge 2	37.6006	37.5991	0.0015	0.005
Muck 1	24.1551	24.1535	0.0016	0.005
Muck 2	33.7864	33.7828	0.0036	0.012
Side Stream 1	34.8452	34.8427	0.0025	0.008
Side Stream 2	34.2299	34.2275	0.0024	0.008
Moore Road 1	36.8563	36.8545	0.0018	0.006
Moore Road 2	40.7337	40.7289	0.0048	0.016

TVS for August 9, 2013

Samples	Weight of crucible before 550C oven (g)	Weight after oven (g)	TVS (g)	Grams per l of water
Sandy 1	36.2239	36.2207	0.0032	0.128
Sandy 2	33.5853	33.5815	0.0038	0.152
East side 1	37.6022	37.5997	0.0025	0.100
East side 2	24.8257	24.7355	0.0032	0.128
N. of bridge 1	21.5354	21.5334	0.0020	0.080
N. of bridge 2	23.9696	23.9664	0.0032	0.128
Muck 1	35.9405	35.9377	0.0028	0.112
Muck 2	24.7367	24.7331	0.0045	0.180
Land bridge 1	34.8431	34.8419	0.0012	0.048
Land Bridge 2	38.5329	38.5298	0.0031	0.124
Fish Pond 1	24.5403	24.5367	0.0036	0.144
Fish Pond 2	34.2349	34.2304	0.0025	0.100
Side Stream 1	25.6647	25.6629	0.0018	0.072
Side Stream 2	24.4731	24.9706	0.0025	0.100
Moore Road 1	24.1567	24.1538	0.0029	0.116
Moore Road 2	40.7348	40.7312	0.0036	0.144

TVS for September 22, 2013

Samples	**Crucible Weight before 550C (g)**	**Weight After Burn (g)**	**TVS (g)**	**Grams per l of water**
Sandy 1	25.0404	25.0397	0.0007	0.028
Sandy 2	36.7988	36.1977	0.0011	0.044
East Side 1	37.651	37.6492	0.0018	0.072
East Side 2	26.8988	26.8982	0.0006	0.024
North of Bridge 1	43.498	43.4944	0.0036	0.144
North of Bridge 2	41.0007	41.0015	0.0008	0.032
Muck 1	37.1581	37.1556	0.0025	0.100
Muck 2	33.9817	33.9815	0.0002	0.008
Land Bridge 1	36.2145	36.214	0.0005	0.020
Land Bridge 2	40.73	40.7287	0.0013	0.052
Fish Pond 1	24.5415	24.395	0.002	0.080
Fish Pond 2	24.6021	24.6006	0.0065	0.260
Side Stream 1	42.8549	42.853	0.0019	0.076
Side Stream 2	42.181	42.1793	0.0017	0.068
Moore Road 1	34.2242	34.2226	0.0016	0.064
Moore Road 2	33.577	33.575	0.002	0.080

TVS for February 21, 2014

Samples	**Crucible weight before 550 C oven (g)**	**After oven (g)**	**Volatile Solids (g)**	**Grams per l of water**
Sandy 1	64.2924	64.2843	0.0081	0.324
Sandy 2	34.1841	34.1792	0.0049	0.196
East Side 1	34.5117	34.5085	0.0032	0.128
East Side 2	42.2223	42.2192	0.0031	0.124
North of Bridge 1	37.1773	37.1745	0.0028	0.112
North of Bridge 2	28.6367	28.6291	0.0076	0.304
Muck 1	38.0593	38.0553	0.004	0.160
Muck 2	39.6666	39.6559	0.0107	0.428
Land Bridge 1	26.7848	26.7815	0.0033	0.132
Land Bridge 2	41.5463	41.5448	0.0015	0.060
Fish Pond 1	28.3388	28.3352	0.0036	0.144
Fish Pond 2	27.7025	27.6989	0.0036	0.144
Side Stream 1	64.9111	64.9059	0.0052	0.208
Side Stream 2	60.5703	60.5678	0.0025	0.100
Moore Road 1	26.4995	26.4965	0.003	0.120
Moore Road 2	26.5669	26.5645	0.0024	0.096

TVS for April 6, 2014

APPENDIX D

All data was retrieved from 'Community Collaborative Rain, Hail, and Snow Network, www.cocorah.org/viewdata/statedailyprecipreports.aspx?state=oh.

Season	Dates	Inches or rain
Summer 1	July 4th	0.09
	July 4th	0.3
	July 6th	0.04
	July 7th	0.01
	July 8th	0.32
	July 9th	0.32
	July 10th	0.55
	July 11th	0.58
		2.21
Summer 2	August 8th	0.74
	August 9th	0.29
		1.03
Fall	September 21st	1.07
	September 22nd	0.47
	September 23rd	0.02
		1.56
Winter	February 17th	0.02
	February 18th	0.78
	February 19th	0.06
	February 20th	NA
	February 21st	0.27
		NA
Spring	April 4th	0.69
	April 5th	0.44
		1.13

APPENDIX E

Site locations that correspond to the site identification.

Site Identification
Site 1- Landbridge
Site 2- East Side
Site 3- Sandy
Site 4- Muck
Site 5- Pipe North of Bridge
Site 6- Fish ponds
Site 7- Side stream
Site 8- Moore Road