EFFECTS OF URBANIZATION ON A SMALL RURAL WATERSHED

by

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ABSTRACT

The Moses Creek watershed, northeast of Stevens Point, Wisconsin, although quite small, has the potential for substantial downstream impact. The creek drains directly into the storm sewer system for the City of Stevens Point. The storm sewers are unable to handle the increased flow when flood potential is reached in the spring, and after heavy summer rains. At this time there are few buffers to ease the threat of flooding caused by Moses Creek as it enters Stevens Point and once it enters the storm sewer system. Possible solutions to abate flooding within Stevens Point would be protection of the headwaters of Moses Creek and restoration of wetlands within the watershed.

This study of Moses Creek will; gather stream flow and precipitation data for the watershed, generate a database using appropriate software, evaluate hydrologic modeling programs to determine the one best suited for Moses Creek, calibrate[1] that model to provide a realistic representation of the watershed, and use the model to simulate potential future effects on the Moses Creek watershed.

Precipitation and stream flow data were analyzed to determine the hydrologic characteristics of the Moses Creek watershed. These data were used to calibrate a runoff model, the United States Army Corps of Engineers, Hydrologic Engineering Center – Hydrologic Modeling System (HEC-HMS). Environmental Systems Research Institute (ESRI) ArcView®, a software mapping tool using landuse, elevation, roads, soils, and property boundaries, facilitates definition of watershed hydrologic parameters and allows these parameters to be incorporated into HEC-HMS. The HEC-HMS model has shown a high degree of correlation between measured and modeled runoff. Agreement between

[1] HEC-HMS model calibration is fully discussed on page ##.

measured and modeled data make it possible to manipulate parameters of the modeled watershed to evaluate the impact of land use changes in the actual watershed.

Model runs reveal that the Moses Creek watershed is sensitive and variable to subtle changes in characteristics of the watershed including precipitation, vegetation, soil saturation, pervious cover or lack of it. Subtle character changes have dramatic influence on downstream discharge volumes, duration of peak discharge and lag time between rainfall event and flood event.

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INTRODUCTION

The Moses Creek Watershed, (see Figure 1 on the next page) has substantial potential for impacting downstream land and populations. The watershed, of 7.6 square miles, lies above the City of Stevens Point and drains into the city's storm sewer system, continuing one and one-half miles through the city before emptying into the Wisconsin River. From the 1930's through the 1970's, Moses Creek posed considerable problems for downtown Stevens Point, flooding store basements and nearby streets (Donohue 1980). The stream drained into the Crosby Avenue Slough and was held there before being pumped over a bank to the Wisconsin River (Figure 2). After spring runoff and heavy rains, the pumps could not keep up causing downtown flooding. The pumps at the slough were necessary because the Consolidated Papers dam on the Wisconsin River was built in the 1930's, no longer allowing natural drainage from the slough to the river (Donohue 1980).

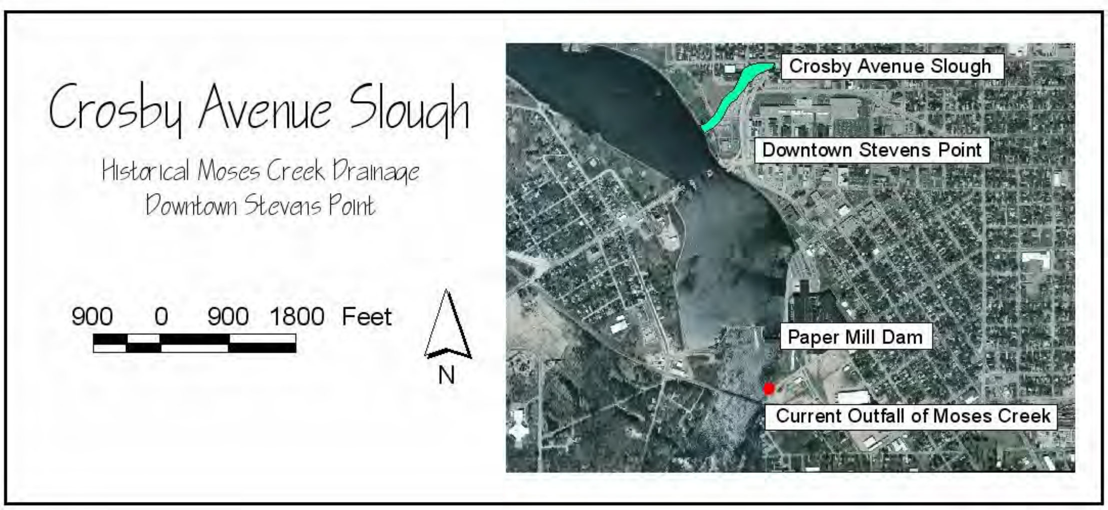

Figure 2. The historic outlet of Moses Creek was near the Crosby Avenue Slough (no longer in existence). The paper mill dam was raised in the 1930's requiring Moses Creek to be pumped into the Wisconsin River. Reconstruction of the storm sewers in the 1980's brought Moses Creek to the foot of Wisconsin Street, below the dam.

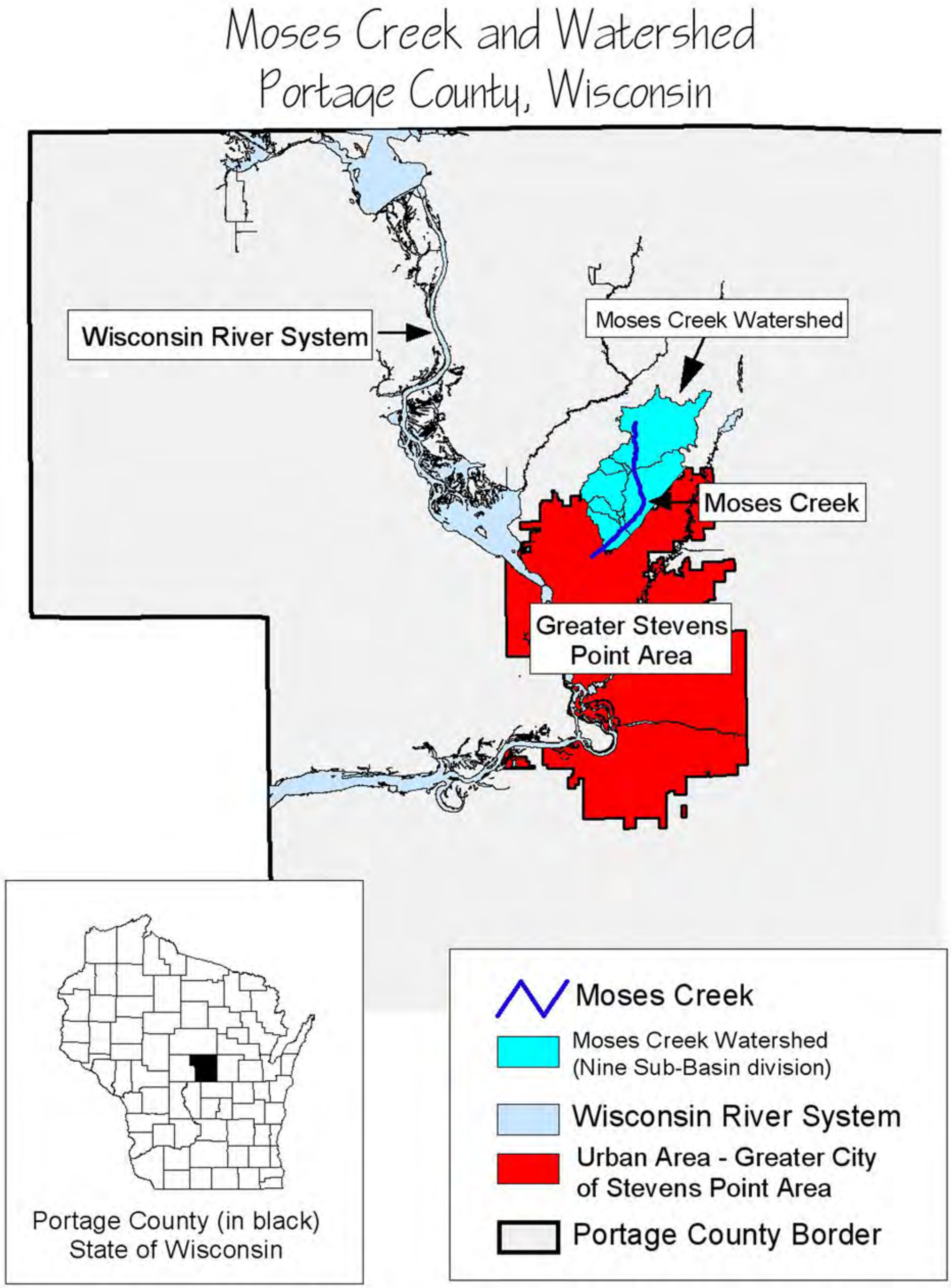

Figure 1. The location of Moses Creek and its Watershed in relation to the Wisconsin River and the City of Stevens Point.

During the 1980's the storm sewers were upgraded and Moses Creek was redirected underground through concrete pipe from Michigan Avenue to the Wisconsin Street outlet below the paper mill dam (Donohue 1980). Upstream from Michigan Avenue, Moses Creek continues to present flooding problems.

In the spring, and after heavy summer rains Moses Creek can flood, in which case, the City storm sewers are not able to handle the increased flowage. Several buildings of the University of Wisconsin/Stevens Point are built on or near the historic streambed within the city of Stevens Point. Given persistent high water in the sewer, basements in some of these buildings may flood, which over time jeopardizes their foundations and structural integrity. Flooding from Moses Creek has, in the past, also, overrun into the neighborhood north of State Highway 66, (Stanley Street), and east of Minnesota Avenue (Figure 3 lower inset map). A large storm could as well overflow Moses Creek into Lake Joanis and degrade the water quality of the lake. It is likely that, new homes and wider streets built north of U.S. Highway 39/51 and additional commercial interests near the Highway 66 and 39/51 interchange will have a serious impact downstream within the Moses Creek corridor. At this time, there are few buffers to ease the flooding caused by Moses Creek. Protection of the headwater area and the restoration of wetlands within the watershed are important factors when considering the possibility of future flooding within the city (Donohue 1980).

Not surprising, Stevens Point is not alone with the problem of urban runoff, with this issue being a headache for many municipalities throughout the United States. Since the enactment of the Clean Water Act in the mid-1970's, federal agencies from the

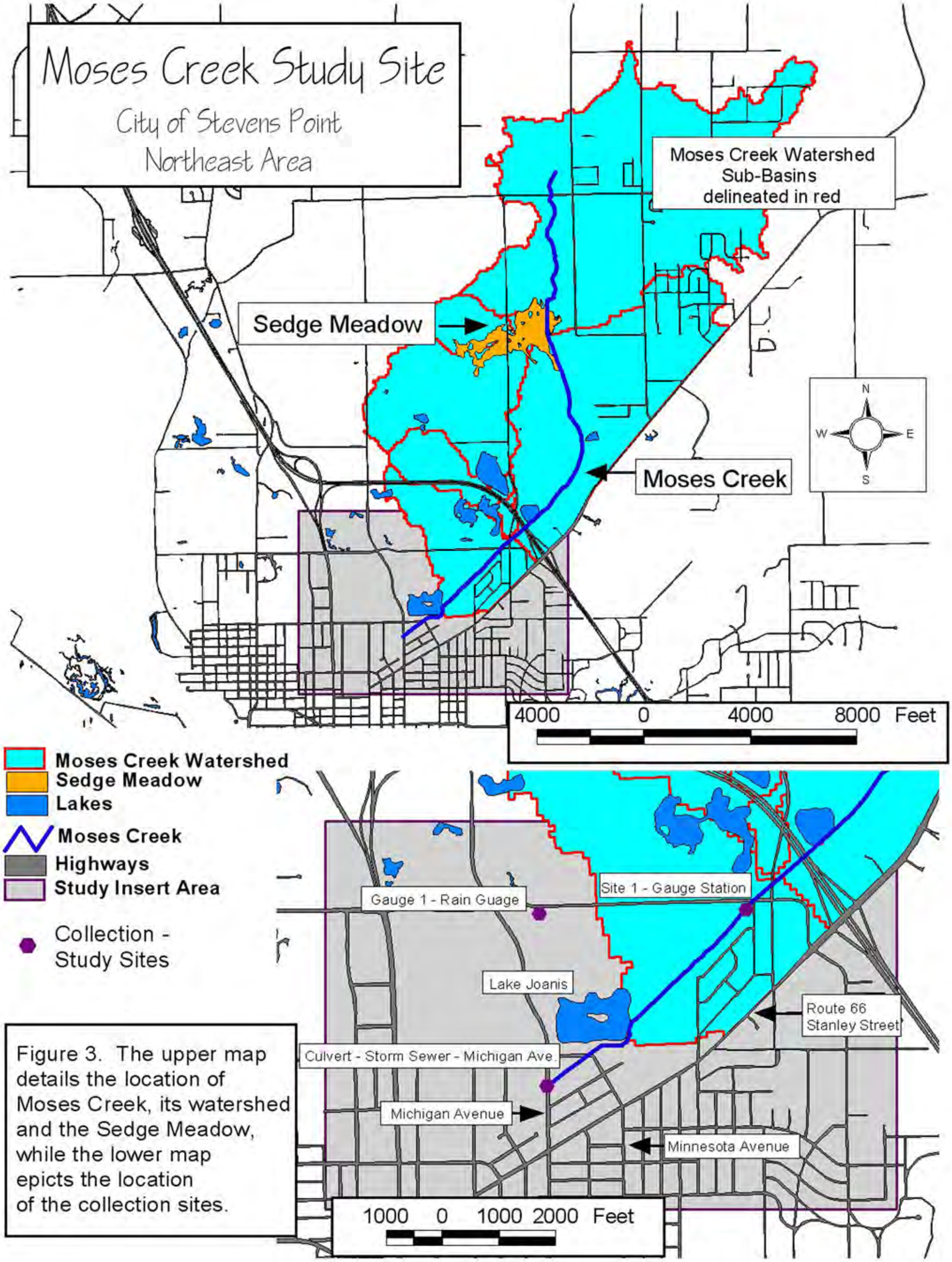

Figure 3. The upper map details the location of Moses Creek, its watershed and the Sedge Meadow, while the lower map epicts the location of the collection sites.

Environmental Protection Agency (EPA) and the Natural Resource Conservation Service (NRCS) down to county and local governments are trying to deal with this persistent problem. Urban development alters the runoff characteristics of a drainage basin, primarily through increases in impervious areas, stream channel alterations, storm sewer development, and curb and gutter streets. It is evident that as cities grow, there is more and more impervious cover, and this adds to urban runoff (U.S. Geological Survey 1996). There has been a growing public awareness of, and a desire for, a change in the way our nation's waters are managed, for protection of homes and property since the implementation of the Clean Water Act.

In the early years after the Act was established point source pollution garnered the most attention, but non-point source pollution eventually was seen as more of a problem. One of these concerns was storm water runoff. As cities to grow, they will continue to affect the quantity and quality of the runoff. Streets, houses, parking lots, buildings, malls and driveways result in more impervious areas and consequently there is more runoff from each rainfall event (Bost 1980). Contact with surface wastes on these impervious areas adds considerable pollutants to the runoff. Oils, fuels and other compounds from automobiles and trucks, salts and other chemicals used in road and highway maintenance and additional suspended solids, sand and silt, can all be included in runoff. The increase in pollutants raises two questions: 1) how do metropolitan areas deal with the added runoff and, 2) how can the runoff problem be dealt with when urban areas are expanding and adding more impervious surfaces? These questions are certainly multifaceted that vary depending on the urban environment. In this case study the quantity of runoff is the main issue, and how to regulate runoff so that it doesn't become a flooding problem.

LITERATURE REVIEW

Working with Nature

Anne Whiston Spirn[2] says, "It is time for those who care about restoring the land to embrace the city as well as the countryside" (Spirn 1992). Spirn explains, nature is a continuum with wilderness at one pole and the city at the other. The air we breathe is a mixture of gases. Whether these gases are a mixture of exhaust fumes and smoke in the city, or soft breezes and scents of flowers in the country, they are part of nature. Our presence on the sidewalks and streets of the city or on the boulders and cobble of a mountainside both affect the temperature, precipitation and energy that drive heat gain and runoff (Spirn 1992). Understanding and working with runoff instead of against it is one of the ideas Spirn sets forth in her philosophy. Different cities are using different means to accomplish runoff/flood control, such as in Boston, Massachusetts who wanted to reduce city flooding. In 1977 in order to curb building and further development within floodplains they began purchasing wetlands along the Charles River (upstream of the city). Denver, Colorado, is collecting storm water in the form of eighteen parks built along the South Platte River to decrease flood damage and increase flood storage. Additionally, they use rooftop storage to help slow inflow of storm water into sewers and the river (Spirn 1992).

[2] Anne Whiston Spirn is a professor of Landscape Architecture at the University of Pennsylvania, Philadelphia.

Elsewhere in the country the issue of flood control continues to raise concern among researchers and elected officials. In 1979, President Jimmy Carter issued an executive order recognizing that urbanization outside of the floodplain, but within the watershed, usually increases both the frequency and magnitude of flood events. The order required the federal government to give special emphasis to watershed management, including use of nonstructural flood control alternatives (Bost 1980). Further studies have demonstrated that an increase in impervious cover, and accompanying structural drainage improvements, increases runoff rates that lead to higher flood peaks, higher total flow volumes, and shorter lag times between rainfall and a flood event (Bost 1980). Flooding associated with Moses Creek is no different.

Studies of the Moses Creek Watershed indicate the potential for increased flows along the 39/51 and 66 highway corridors (Donohue 1980). Earlier studies quoted in the Donohue report (authorized by the City of Stevens Point) indicate that flooding within the Moses Creek corridor has persisted for some time within the City of Stevens Point. These studies focused on the business and residential areas close to downtown and several recommended diverting Moses Creek eastward toward the Plover River (Donohue 1980). Wisely, the City of Stevens Point diverted the Moses Creek outfall to below the local paper mill dam, at the end of Wisconsin Street, based on the Donohue report's findings. Since that report was written, however, much has changed within the watershed. Commercial and residential development along the stream corridor has grown dramatically. Yet the issues of runoff have not changed. The decrease of pervious area continues to result in potentially overwhelming volumes of runoff and these volumes could exceed storm sewer capacities even though the sewer line capacities were increased in the 1980's. Hydrologic modeling is one avenue toward determining the effects of changes in the watershed.

Two Hydrologic Computer Models

Since the 1960's, computers have replaced the hand method of analyzing hydrologic data. Computer programs have continued to evolve and have become more powerful and efficient in understanding hydrologic processes. The U.S. Army Corps of Engineers HEC (Hydrologic Engineering Center) and the AGNPS (Agricultural Non-point Source) software programs are two widely used and accepted hydrologic modeling routines. They were examined for their ability to manipulate and analyze watershed data as well as the capability to handle the Moses Creek project. Both were evaluated to determine the ideal (i.e. efficiency and applicability) program formulations fitting Moses Creek and its runoff. Both were examined for use from a normal desktop PC. Each program was compared in its ability to handle the data input and small size of the study watershed.

HEC (Hydrologic Engineering Center) is a collection of software for water resource analysis, which continues to be developed by the U.S. Army Corps of Engineers for use in flood control, hydropower, and navigation (Feldman 1993). Since its introduction in 1966, HEC software has spread to worldwide use and has grown with expanding computer capabilities and technologies. A specific program module within HEC is the HEC-HMS (Hydrologic Modeling System). This program includes single event and continuous simulation of runoff and can utilize several hydrologic components

(Pabst 1993), making it a good choice for working within a small watershed, like the Moses Creek Watershed.

AGNPS (Agricultural Non-point Source) is also an excellent choice for hydrologic modeling. AGNPS was developed to include hydrology, sedimentation, and chemical transport. Initially, AGNPS was also a single event model, but it evolved into the Annualized Agricultural Non-point Source (ANN-AGNPS) continuous version model. Like AGNPS it includes parameters such as overland runoff volume, channel flow runoff volume, peak flow discharge rates, field erosion, channel sediment transport, deposition of soil by particle size, nutrient yields, and chemical oxygen demand (COD) (Needham 1993). AGNPS and ANN-AGNPS are both good choices for small watersheds, because the nature of AGNPS and ANN-AGNPS make data input tedious and troublesome for large watersheds. Although not the specific focus of this study, it is important to point out that large watersheds and their modeling can shed insight into the dynamics of small watershed modeling.

Control Methods in a Large Watershed

The Cypress Creek watershed was examined to evaluate the types of hydraulic structures used to manage flooding (Bost 1980). This study was reviewed to compare hydraulic structures of a large watershed to a smaller one. The Cypress Creek watershed is a large drainage area of about 320 square miles and is located 20 miles northwest of Houston, Texas (Bost 1980). The hydrology of the watershed was managed trying to affect change using two different runoff management strategies, structural and nonstructural.

The structural methods included 1) channelization and levee improvements, 2) flood control reservoirs, 3) limiting impervious cover, 4) detention storage, and 5) combinations of the first four strategies (Bost 1980). The most effective approach was using several methods of detention storage to control flooding. These were parking lot detention, rooftop storage, open grassy swales, residential lot detention, natural drainage systems and subdivision detention ponds. These methods yielded a 14% decrease in the 100-year flood peak. By using a combination of the structural approaches there was a decrease of between 12% and 25% for a 100-year flood peak (Bost 1980). Decreases in flood flow were affected using the U.S. Army Corps of Engineers HEC-1 and HEC-2 computer models. Due to the urban runoff in the lower section of the watershed reaching the gauging station before the agricultural runoff from the upper section of the watershed, the models yielded a double-peaked hydrograph (Bost 1980). Moses Creek responds similarly with a double-peaked hydrograph[3], even though it is a much smaller watershed.

The nonstructural approaches include, 1) detention in subdivision depressions, and 2) the acquisition of land, mainly wetlands, to act as sinks to collect runoff and slowly release it to the stream channel. These methods are usually quite effective and much more economical than structural methods if they are available (Bost 1980). Even though the Moses Creek Watershed is considerably smaller than the Cypress Creek watershed, control structures used on Cypress Creek and their effectiveness could be equally useful on Moses Creek or other small watersheds.

[3] Double-peaked hydrographs are characteristic of a watershed that produces two discharge events from one rainfall event.

A Small Watershed Study

At the opposite end of the watershed size spectrum, is the Barney Circle wetland in Washington, D.C. (Winston 1996). This wetland is approximately 1.5 acres and the study focused on an attempt to change the hydrology of this tiny watershed to create a new wetland after proposed highway construction. Barney Circle is a groundwater fed wetland with groundwater supplying more than 80% of the flow into the area. Piezometers were used to determine groundwater contribution, by direction of groundwater flow into or out of the wetland. This wetland provides a significant capacity for storage. Surface water outflow is reduced from 38% to 80% compared to the surface water inflow at the time of a storm (Winston 1996). A numerical groundwater flow model (MODFLOW) was used to reveal a 13% reduction in the recharge area and a 27% decrease in the baseflow discharge of the wetland after the proposed highway construction (Winston 1996). Groundwater continued to contribute 70% to 90% of the wetland outflow after the proposed highway construction as estimated from the model.

Evapotranspiration accounted for only about 10% of the outflow from the wetland. The rapid return to base flow after a rain event supports the evidence that Barney Circle is a groundwater dominant wetland (Winston 1996). The building of the proposed highway would change the topography and the hydrology of the wetland but would not change the hydroperiod. Thus, to recreate this wetland with different plant species would not be practical. A change in the hydroperiod[4] of Moses Creek, which is mainly surface water fed, would affect species change and flow regimes throughout the watershed. Small watersheds are unique and vary greatly, Moses Creek reveals different

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[4] Hydroperiod is the length of time in which water stays in a system. Water on the land for longer than seven days per year is part of the Federal Government guidelines for establishing wetlands.

characters the Barney Creek. Other small watersheds from around the country reveal likenesses to Moses Creek.

Small Urban Watersheds

Many studies tend to focus on the magnitude and the frequency of the instantaneous peak flow of a storm event. Sherwood, in a study in Ohio focused on the magnitude and frequency of flood volumes in 62 small, ungauged, urban streams, similar in size to Moses Creek. All watersheds were smaller than 6.5 square miles (4160 acres). The objective of this study was to analyze flood volumes as a function of duration and frequency. First, by developing multiple regression equations for estimating peak-frequency relations and volume-duration-frequency relations, and secondly, to develop a method of modeling flood hydrographs (Sherwood 1994). The accurate estimation of peak discharge runoff volumes and flood hydrographs are required so that an adequate balance between inflow, outflow, and storage can be achieved in the design of hydraulic structures for the temporary storage of water (Sherwood 1994). The logarithms of the annual peak volumes were fit to the log-Pearson type III frequency distribution curve and, multiple regression equations were developed. The dVT (duration, Volume, Time of recurrence) equations used six different durations 1, 2, 4, 8, 16, and 32 hours and six different recurrence intervals, 2, 5, 10, 25, 50, and 100 years. The variables taken into consideration were area, precipitation, and basin development (percent of impervious cover). For each of the sites the U.S. Geological Survey computer program E784 was used to develop simulated hydrographs for runoff volume. Estimates of volume based on the dVT equations can provide useful information for the design of storage structures.

This approach is conservative, yielding larger volumes, because it takes into account a much longer duration. This will help when designing structures that will not be easily breached at the time of a flood event (Sherwood 1994).

Leon County, Florida has also done stormwater runoff investigations. In conjunction with the U.S. Geological Survey, the county developed a lumped-parameter rainfall-runoff model. This report summarizes methods of collection, processing, and analysis of rainfall-runoff data from the drainage basins (Franklin 1982). The scope of the study was to collect hydrologic data from selected urban drainage systems of the county, to analyze the data, and to develop regression equations that can be used to estimate the magnitude and frequency of floods in other urban areas of the county (Franklin 1982). Water quality samples were collected at some of the gauge sites to provide a database for future studies. Normally, 25 years of observed peak-flood data are needed to make dependable estimates for 50-100 year flood magnitudes (Franklin 1982). To reduce the time required for data collection, rainfall-runoff data collected in the investigation were used to calibrate a lumped-parameter rainfall-runoff model that synthesized a long-term flood record from the long-term rainfall record (Franklin 1982). A log-Pearson type III frequency analysis was then used to establish a flood-frequency for each site, and multiple-regression equations were developed to compare flood frequencies from known (gauged) to similar unknown (ungauged) sites. Moses Creek is similarly ungauged, and building a rainfall-runoff database is an imperative element of a model input to properly characterize it’s watershed.

Flood Control Through Wetland Restoration

The flood of 1993 within the upper Mississippi River basin carried 111 million acre-feet of water past St. Louis, Missouri, causing 16 billion dollars in damage and untold heartache. The excess flow of 40 million acre-feet, if spread at a three foot depth would have covered 13 million acres (Hey 1995). Since the European settlement of the United States, 26 million acres of wetlands have been drained in the upper Mississippi basin alone (Hey 1995). The 1993 flood may never have occurred, had the historic wetlands been in place, since they could have absorbed the excess runoff. The increase of levees has also greatly contributed to increasing flood volume and flood loss. Levees raise flood stage and velocity. They keep the water flow from being retained and its velocity reduced which increases the chance of flooding. The problem was underscored by the flood losses for the upper Mississippi region that have increased 140% in the past 90 years (Hey 1995), mainly being due to wetland loss and levee construction. By strategically placing restored wetlands in the Mississippi River basin, future flooding could easily be avoided. But, how and where to place the wetlands is the main question.

Wetland Restoration

In order to restore a wetland, the first thing to determine is where wetlands had previously existed. One important indicator is the presence of hydric soils. These soils reveal a high organic content from anaerobic conditions common to wetlands. The hydroperiod and water level are important indicators when trying to determine the future success of a restored wetland. Vegetation is also an important part of the new wetland.

Plants and seeds are chosen to best fit the site and the goals of the wetland. Success will be limited without these three indicators; hydric soils, hydroperiod, and wetland vegetation (Mitsch 1993). Restored wetlands should be designed with minimum maintenance; utilization of natural energies, landscape, and climate; and multiple goals. The new wetland needs time to become established and should be designed for function not form (Mitsch 1993). The benefits of wetlands are numerous, flood control, wastewater treatment, stormwater control, non-point source pollution control, water quality improvement, coastal restoration, wildlife and fisheries enhancement, and replacement of habitat (Mitsch 1993). The placement of restored wetlands needs to fit the site and there are several types, instream, riparian, multiple upstream, and terraced (Mitsch 1993). After a wetland is established, an assessment can be made to determine if the goals were met and when further work and maintenance are needed. The creation or re-creation of wetland areas within the Moses Creek Watershed are viable alternatives that could reduce future flooding problems.

Conclusion

There are several different approaches to the management of stormwater runoff. The most practical and economically sound practices are often not attempted until the runoff problem is already too large to be easily fixed. Some proactive examples would be, limiting impervious cover in new development areas before there is a runoff problem or acquiring land to maintain existing runoff protection. Some new approaches could also be quite effective. Rooftop storage can greatly reduce the immediate surge of runoff in a highly urbanized area, and city parks along streams can be used to temporarily slow a storm surge. Small watersheds do not have the ability to buffer flood flow by natural water retention from within, so particular attention needs to be given to the existing areas already capable of flood reduction. Wetland reconstruction is a viable solution to flooding when used as part of the total management package, as well as, the addition of meanders along the stream channel can slow flood flow. But, how can we predict and nodel stream flow and its potential problems? More specifically, can hydrologic modeling successfully predict storm response within the Moses Creek Watershed? What type of construction or maintenance programs can be used to reduce the flood peaks of a storm? The objectives of this research will bring these questions into perspective.

HYPOTHESIS/OBJECTIVES

The idea that urbanization will increase flooding downstream is not a new concept (U.S. Geological Survey 1996). as indicated in the previous section, it is an idea that has spawned many potential solutions to the problem of increased flooding from urbanization. Consequently, the question is posed, whether the Moses Creek Watershed is a potential flooding hazard in the near future? Will an increase in urbanization e.g. housing development, streets, sidewalks, driveways and yards, within the Moses Creek Watershed bring about additional flooding, and to what extent in the City of Stevens Point?

Past studies of the Moses Creek Watershed have been limited and little data of an ongoing nature exists. For this reason and the desire to understand the processes within the Moses Creek Watershed this study has five objectives:

1. Gather stream flow and precipitation data for the Moses Creek Watershed.
2. Generate a database from the gathered information using Microsoft Excel® and Environmental Systems Research Institute (ESRI) ArcView® software.
3. Evaluate leading hydrologic modeling software programs to find the one best suited to the Moses Creek basin.
4. Calibrate the chosen model to the Moses Creek watershed data to provide a realistic representation of the watershed.
5. Use the model to stimulate potential effects future urbanization may have within the Moses Creek Watershed.

STUDY SITE

Location

Moses Creek is located in the town of Hull and the City of Stevens Point in Portage County, Wisconsin and is a tributary of the Wisconsin River (Figure 1 p.2). Moses Creek is a small, intermittent stream with largest flows in the spring and after heavy rains. As Moses Creek enters the City of Stevens Point, it drains into an eight-foot equivalent storm sewer (Donohue 1980). The last mile or so before entering the storm sewer the streambed is channelized. This channelization is likely due to an unsuccessful attempt to drain areas upstream for farming in the 1930's or 40's. The channel was rerouted in the 1970's during the construction of the Sentry World Headquarters and digging of Joanis Lake (also known as Schmeeckle Lake or University Lake). This man-made lake was dug to provide fill for the construction of the Sentry World Headquarters building. Joanis Lake is largely groundwater fed and unaffected by flow from Moses Creek at this time due to the 1970's rechannelization. Up stream from the channelization, the stream widens out into a series of sedge meadows and alder thickets until its origin about two miles north of the city (see figure 3, upper map, Sedge Meadow area). The streambed originates within a large sedge meadow of about 200 acres. Although current maps indicate the streambed extending further north, flow in this part of the stream occurs only under extreme conditions due to high infiltration rates of the surrounding sandy soils.

Area

The Moses Creek Watershed was hand delineated using an USGS 7.5 minute 1:24000 Stevens Point quadrangle (1991 revision). Delineation was verified using the ESRI ArcView® 'watershed delineator'[5] and a portion of the Portage County DEM (Digital Elevation Model). Part of the watershed lies to the east of State Highway 66. Due to the level topography and sandy conditions, it is unlikely that any surface runoff from the area east of the highway contributes to the Moses Creek flow. Groundwater flow east of Highway 66 is to the east and towards the Plover River and the well fields

[5] 'Watershed delineator' is a downloadable extension for ESRI ArcView®. It is available from ESRI.

for the Stevens Point municipal water system. This portion of the watershed was removed from the ESRI ArcView® coverages and the study area, leaving Highway 66 as the eastern boundary of the watershed. The part of the watershed that is within the city limits and enclosed in the storm sewer, from Michigan Avenue downstream to the confluence with the Wisconsin River, was also excluded from the study area. The Moses Creek Watershed was finally defined as covering 6.1 square miles (3904 acres), encompassing the surface water contributing area of the watershed. For this study the basin was divided into 9 subwatersheds, ranging in size from one acre to 1653 acres (Figure 4). These subwatersheds were also delineated from ArcView®. The length of the watershed is approximately 4.67 miles. The width of the watershed is approximately 2 miles. The watershed is more or less oval draining northeast to southwest.

Topography

Topography of the watershed is relatively flat with a gradient of about ten feet per mile. The elevation at the northern most part of the watershed is about 1130 feet above sea level, while the elevation at the entrance to the storm sewer is 1095 feet. The highest point in the watershed is a hill on the western edge of the watershed boundary; its elevation is 1165 feet. Groundwater topography is likewise relatively flat and close to the surface, ranging from approximately 1125 feet in the north to 1090 feet at the entrance to the storm sewer (Holt 1965). The direction of groundwater flow is southwesterly, the same as the stream flow, toward the Wisconsin River. Even at the driest conditions in late summer Moses Creek usually has flow out of the sedge meadow, but ceases downstream of the sedge meadow. This evidence of loss of flow downstream from the sedge meadow may indicate that Moses Creek serves as a groundwater recharge stream.

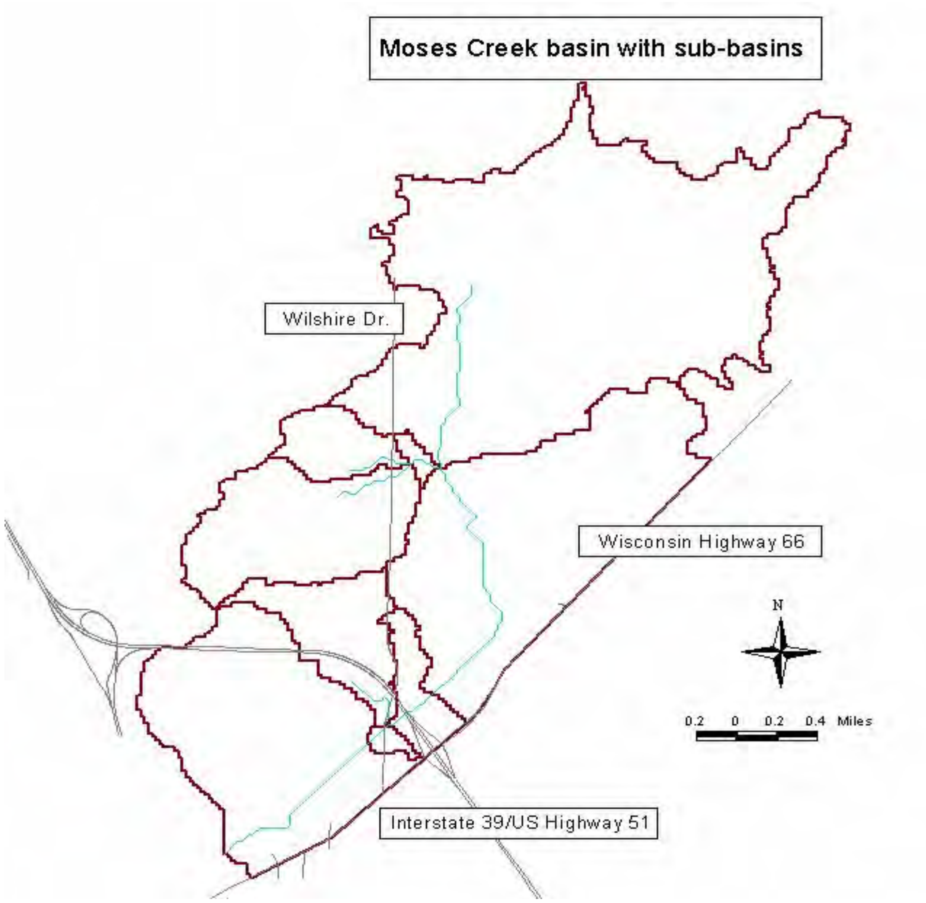


Figure 4. Moses Creek basin and subbasins. Wisconsin Highway 66 is the eastern border of the watershed. Interstate 39/US Highway 51 bisects the southern 1/4 of the watershed and Wilshire Dr. bisects the watershed north and south.

Landuse/Vegetation

The watershed has a mix of deciduous and coniferous forest, and pine plantation. The wooded areas make up approximately 58% of the watershed. The remaining area is approximately 13% agricultural, 13% residential, 8% marshes, sedge meadows and grasses, 3% roads, 2% water and 1% recreation. The agricultural area consists mainly of, field corn, alfalfa and pasture. The residential areas are single-family homes. There are two mobile home parks in the watershed with an area of about 80 acres. The marsh, sedge and grass sections of the watershed lie near the Moses Creek streambed, the major part of these being the sedge meadow, about 200 acres, at the headwater area of the stream. Eggers and Reed classified the headwater area is a 'sedge meadow' type wetland (Eggers 1997). The meadow is dominated by hummock sedge (Carex stricta) with a mix of other sedges (Carex), rushes (Scirpus) and grasses (Calamagrostis). Inroads of woody shrubs are in place, willows (Salix) and a few islands of white pine (Pinus strobes).

Soils

Soils of the Moses Creek Watershed are primarily sandy to loamy sand. There are at least eight separate soil series within the watershed and several of the series have sub-series as well. Roscommon is the soil series that dominates the streambed and the sedge meadow areas and is described with a surface layer of nine inches of muck followed by 17 inches of olive-brown medium sand and 34 inches of grayish-brown medium to course sand (USDA 1978). The Plainfield series and the Friendship series are dominant throughout the remainder of the watershed, comprising over 50% of the soil types. Plainfield series is described as five inches of very dark grayish-brown loamy sand, nine inches of light brown loamy sand, 20 inches of yellowish-brown medium sand (USDA 1978). Friendship series is described as seven inches very dark grayish-brown loamy sand, 12 inches yellowish-brown loamy sand, and 11 inches yellowish-brown medium sand. A general description of the three dominant soil series, Roscommon, Plainfield and Friendship from the "USDA-Soil Survey of Portage County, Wisconsin" (1978), is; a deep medium to course sand, poorly to moderately well drained, level to somewhat steep. Permeability is rapid and available water capacity is low. The soils are saturated at a depth of one foot to five feet. Depth to bedrock is more than five feet.

These areas are used for pasture, crops and woodlands. Dancy, Point, Richford, Rockers and Mosinee soil series are interspersed throughout the remainder of the watershed. These soil series are deep sandy loam soils that are well drained to poorly drained and are level to gently sloping.

Weather

The climate in central Wisconsin is temperate humid, with relatively warm humid summers and cold snowy winters. The average annual temperature at Stevens Point is 44° F. The reported maximum temperature is 108° F and the minimum temperature is -48° F. The average yearly precipitation is 32 inches, with 65% falling during the growing season. Forty-three inches of snow is the average snowfall (Holt 1965).

Geology

Moses Creek lies within an outwash plain originating in the Hancock terminal moraine about 5 miles east of the basin (Holt 1965). The underlying crystalline bedrock is Precambrian and impermeable. Made mostly of granite, outcroppings of gneiss, schist, shale, greenstone and quartzite breaks the surface in some places. The depth of the outwash within the watershed may be as deep as 50 feet (Holt 1965). The outwash consists of unconsolidated sands and gravel with a sand and loamy sand surface horizon.

METHODS

The hypothesis for this study is that increased surface impermeability in the watershed of Moses Creek will cause flooding within Stevens Point. The objectives of this study provide a framework for description of the methods developed to test the hypothesis.

1.) Gather stream flow and precipitation data for the Moses Creek watershed.

Stream depth, flow and discharge data were collected at the bridge where the Green Circle Trail crosses Moses Creek, on the eastern edge of Schmeeckle Reserve.

Stream flow data was collected beginning June 1998 using an Isco 1870 bubble level meter. Since September 5, 1999, a Sigma 950 digital recording level meter replaced the Isco meter. Level meter records were checked weekly or biweekly and data was collected monthly. The Isco meter data was collected on paper roll charts and hand transcribed into Microsoft Excel®. The Sigma data was downloaded directly into spreadsheet form. The level meters were housed in a theft prevention container made from 36 in. culvert material with a lockable cover and secured to the ground with steel posts. This deterred damage to the units during operation.

Stream discharge was measured two to three times weekly throughout the summers of 1998 and 1999 with a Marsh/McBirney flow meter and top-down wading rod. For each sample the stream cross-section was divided into one-foot segments, for making velocity and depth measurements (Figure 5). A discharge rating curve for this point on the stream was calculated.

Cross-Section of Moses Creek at the Schmeeckle Reserve Green Circle Bridge

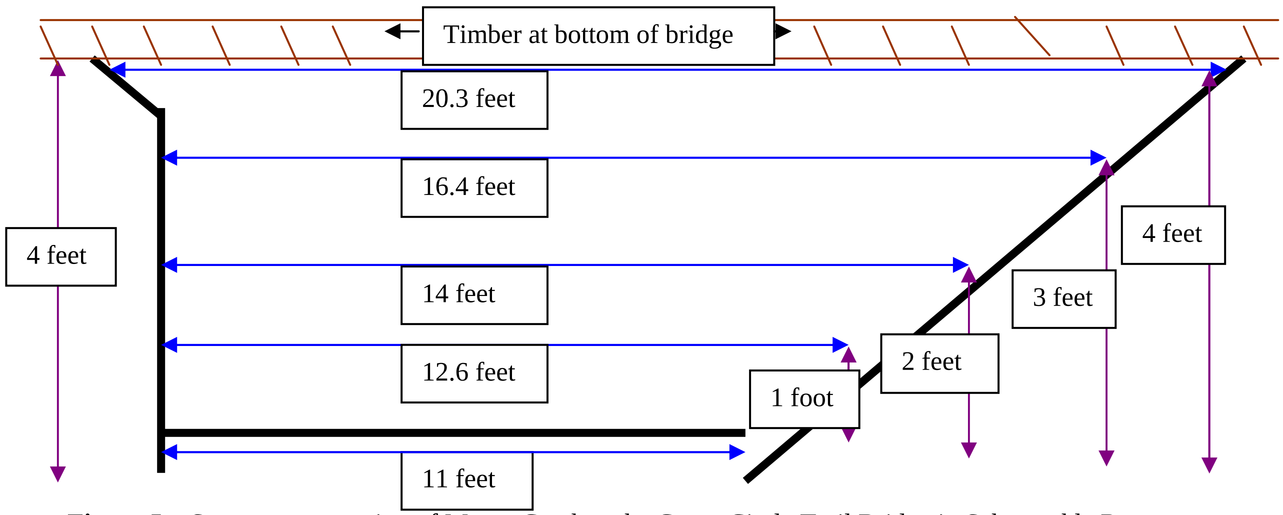


Figure 5. Stream cross section of Moses Creek at the Green Circle Trail Bridge in Schmeeckle Reserve. Cross-section of Moses Creek at 'Site 1' gauging station.

Rainfall data was collected beginning in September of 1998 using a Bendix weighing bucket rain gauge. The rain gauge was placed on the roof of the Schmeeckle Reserve Visitor Center to prevent tampering and vandalism. The Schmeeckle Reserve Visitor Center and the rain gauge are about one-half mile from the gauge station at the Green Circle Bridge. The rain gauge chart was changed weekly; the mechanical clock driving the chart needed to be wound weekly. Raingauge chart data were transcribed into spreadsheet form, e.g. Microsoft Excel®.

2.) Generate a database from the gathered information using Microsoft Excel® and ESRI ArcView®.

<u>Microsoft Excel®</u>

Data collected from the rain gauge on the paper charts was transcribed into

Microsoft Excel® spreadsheet (Figure 6).

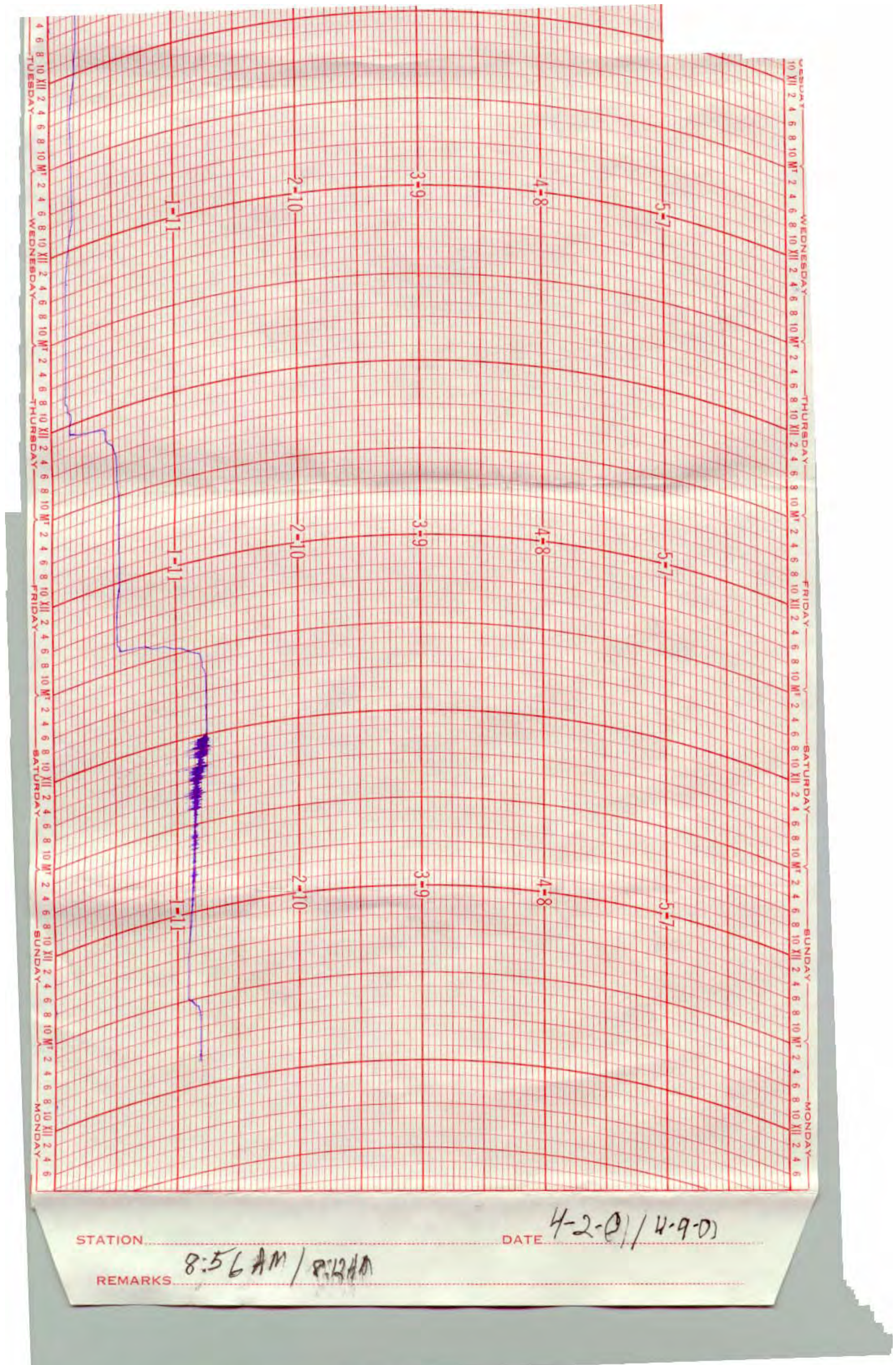


Figure 6. Portion of a rain gauge chart showing the weekly rain gauge data gathered throughout the study period. Complete converted rain gauge chart data is found in Appendix B on CD.

The Excel® columns include the date of collection, the time of day in 15-minute increments, the amount of precipitation for that 15-minute time frame and the cumulative precipitation for the month.

Date d-m-yr	Time 15 min int.	Precipitation Total		Precipitation by 15 min. int.		
8-Jul-99	19:00	1.680		0.000		
8-Jul-99	19:15	1.680		0.000		
8-Jul-99	19:30	1.680		0.000		
8-Jul-99	19:45	2.110		0.430		
8-Jul-99	20:00	2.530		0.420		
8-Jul-99	20:15	2.700		0.170		
8-Jul-99	20:30	2.870		0.170		
8-Jul-99	20:45	3.030		0.160		
8-Jul-99	21:00	3.200		0.170		
8-Jul-99	21:15	3.240		0.040		
8-Jul-99	21:30	3.270		0.030		
8-Jul-99	21:45	3.300		0.030		
8-Jul-99	22:00	3.340		0.040		
8-Jul-99	22:15	3.360		0.020		
8-Jul-99	22:30	3.460		0.100		
8-Jul-99	22:45	3.460		0.000		
8-Jul-99	23:00	3.460		0.000		
8-Jul-99	23:15	3.460		0.000		
8-Jul-99	23:30	3.460		0.000		
8-Jul-99	23:45	3.460		0.000		
9-Jul-99	0:00	3.460		0.000		
9-Jul-99	0:15	3.460		0.000		
9-Jul-99	0:30	3.460		0.000		
9-Jul-99	0:45	3.460		0.000		
9-Jul-99	1:00	3.460		0.000		

Table 1. The spreadsheet/table above is representative of a small portion of the rainfall data collected. It shows most of the storm of July 8, 1999. Complete rainfall data can be found in Appendix B on CD.

There are 96 entries for each day and 2880 entries for a 30-day month. Data is kept in single monthly files to reduce the enormity of the nearly two years of entries. Complete rainfall data can be found in Appendix B on CD. At the end of each month, the result is a running total of precipitation for each 15-minute increment and a total accumulation for the month, both of which would be equal if entries are correct. This is a simple way to check for errors in data entry.

Data collected from the bubble meters was transcribed from the roll charts of the Isco 1870 meter into Microsoft Excel® in the same manner as the precipitation charts (Figure 7).

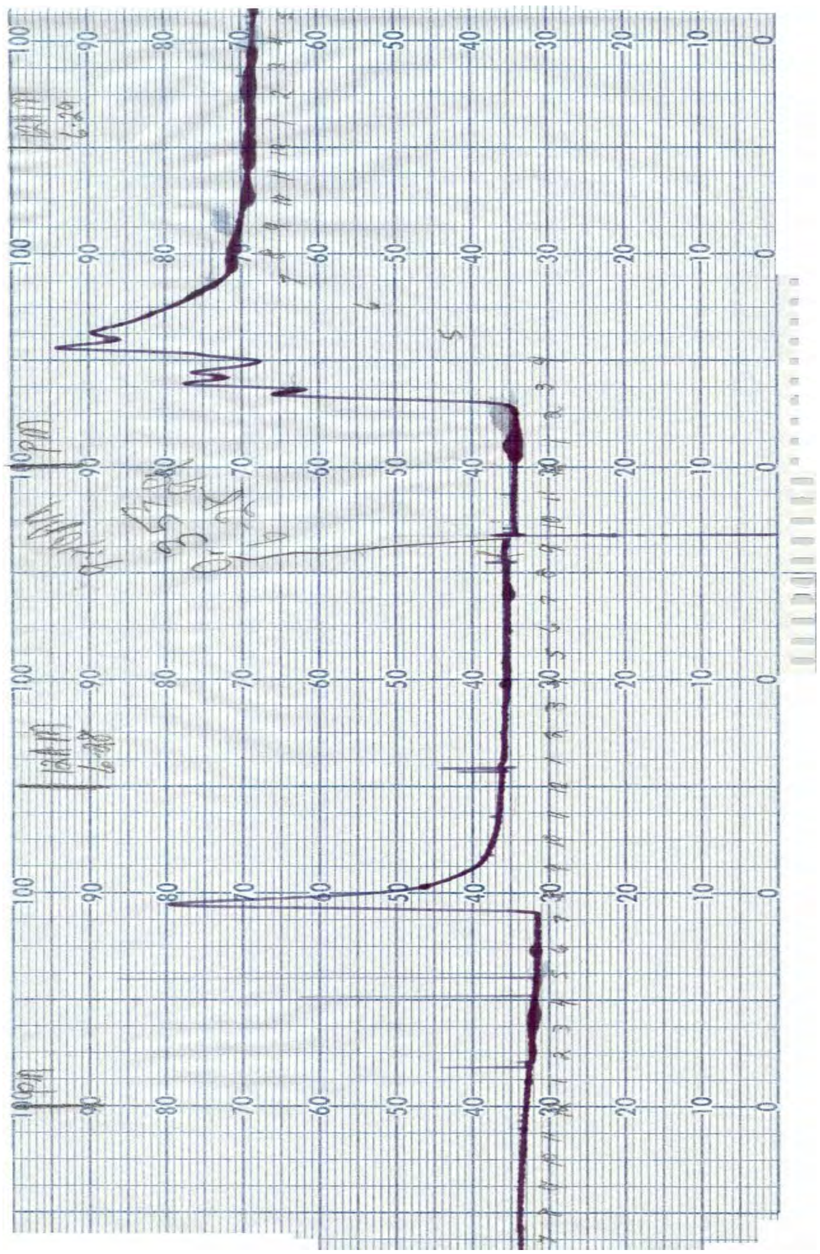


Figure 7. The chart above is representative of a small portion of the stage data collected. This chart is part of a data roll from the ISCO 1870 meter. Complete stage data can be found in Appendix C on CD.

Data was logged for date, time of entry, and depth/level/stage of the stream in 15-minute increments (Table 2). Complete stage data can be found in Appendix C on CD.

Date	Time	Level	
day/mo/yr	24hr clock	feet	
8-Jul-99	19:00	0.420	
8-Jul-99	19:15	0.420	
8-Jul-99	19:30	0.420	
8-Jul-99	19:45	0.420	
8-Jul-99	20:00	1.000	
8-Jul-99	20:15	0.930	
8-Jul-99	20:30	1.000	
8-Jul-99	20:45	0.960	
8-Jul-99	21:00	1.000	
8-Jul-99	21:15	1.270	
8-Jul-99	21:30	1.150	
8-Jul-99	21:45	1.100	
8-Jul-99	22:00	1.140	
8-Jul-99	22:15	1.100	
8-Jul-99	22:30	1.120	
8-Jul-99	22:45	1.150	
8-Jul-99	23:00	1.100	
8-Jul-99	23:15	1.060	
8-Jul-99	23:30	1.040	
8-Jul-99	23:45	1.020	
9-Jul-99	0:00	1.000	
9-Jul-99	0:15	1.000	
9-Jul-99	0:30	0.990	
9-Jul-99	0:45	0.990	
9-Jul-99	1:00	0.980	

Table 2. The spreadsheet/table above is representative of a small portion of the stage data collected. It shows part of the storm of July 8, 1999. Complete stage data can be found in Appendix C on CD.

The Sigma 950 meter can be programmed to collect information in a variety of ways. The Sigma data log program was designed to collect data in the same manner as that used with the Isco meter, date, time of collection and depth/level/stage of the stream. The Sigma logger stored the data digitally and was downloaded monthly in dbf format to a laptop and transferred to a PC for analysis. The dbf files were saved as Excel® files.

Stream discharge and stage data collected for the summers of 1998 and 1999 were graphed with the Excel® program to develop a rating curve. One hundred thirty discharge samples were collected for the two-year study period (Appendix D on CD). Using Excel® to generate a X-Y scatter graph, the measured stage readings (ft.) were plotted against measured discharge (cfs). The trendline feature of Excel® was used to define the rating equation. The resulting trendline produced an anomaly that indicated values for discharge below zero. This may be the result of many stage readings close to zero. To adjust for the anomaly, the log of discharge was plotted against the stage, producing a satisfactory graph without any negative Q (discharge) (Figure 8). The trendline for this graph generated the equation that was used as the rating curve, Y= (1.3017 Ln(x)+0.6809). Where X = stage and Y = log discharge. Discharge/Q = 10^Y (Chow 1964)(Maidment 1993).

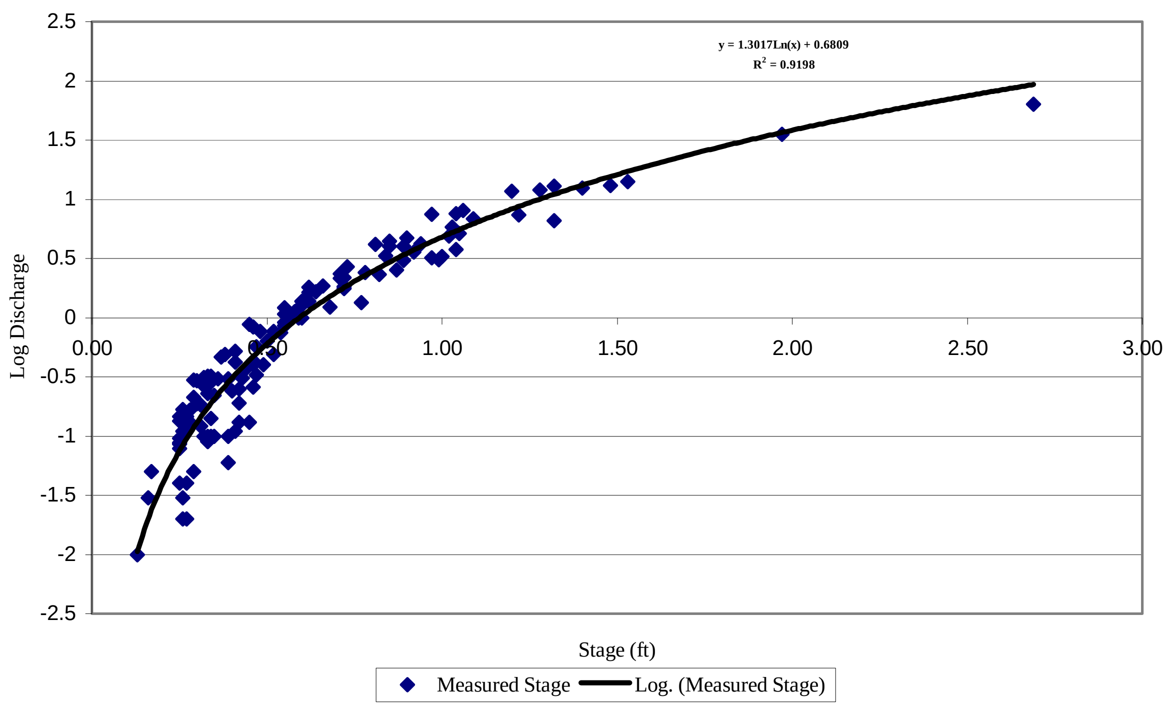


Figure 8. The log of discharge(Q) plotted against stage produces a rating curve and formula to be used to determine discharge for all stage values for the study period.

Discharge derived from the rating curve was analyzed against measured discharge. The regression resulted in R^2 value of 0.96 at both the 95 and 99 percent confidence levels (Table 3). A routine correlation of the derived and measured discharge revealed 98% correlation.

Correlation		
	calculated Q	*discharge/Q*
calculated Q	1	
discharge/Q	**0.980163516**	1

SUMMARY OUTPUT @ **95% confidence**

Regression Statistics	
Multiple R	0.980163516
R Square	0.960720519
Adjusted R Square	**0.960408777**
Standard Error	1.81917318
Observations	128

SUMMARY OUTPUT @ **99% confidence**

Regression Statistics	
Multiple R	0.980163516
R Square	0.960720519
Adjusted R Square	**0.960408777**
Standard Error	1.81917318
Observations	128

Table 3. Correlation of derived and measured discharge. Regression statistics for derived and measured discharge.

Stage data collected throughout the study period was converted to discharge using the rating curve (Table 4). At this point all data is in a form that will facilitate input, analysis and discussion within the preferred program, HEC-HMS.

Moses Creek level is converted to discharge using the formulas
Y = (1.3017 Ln(x)+0.6809) and Disch./cfs = 10^Y

Date	Time/24hr	Level/ft	Precip/15min	Precip/total	log q	Disch./cfs
8-Jul-99	19:00	0.420	0.000	1.680	-0.448	0.356
8-Jul-99	19:15	0.420	0.000	1.680	-0.448	0.356
8-Jul-99	19:30	0.420	0.000	1.680	-0.448	0.356
8-Jul-99	19:45	0.420	0.430	2.110	-0.448	0.356
8-Jul-99	20:00	1.000	0.420	2.530	0.681	4.796
8-Jul-99	20:15	0.930	0.170	2.700	0.586	3.859
8-Jul-99	20:30	1.000	0.170	2.870	0.681	4.796
8-Jul-99	20:45	0.960	0.160	3.030	0.628	4.244
8-Jul-99	21:00	1.000	0.170	3.200	0.681	4.796
8-Jul-99	21:15	1.270	0.040	3.240	0.992	9.818
8-Jul-99	21:30	1.150	0.030	3.270	0.863	7.292
8-Jul-99	21:45	1.100	0.030	3.300	0.805	6.382
8-Jul-99	22:00	1.140	0.040	3.340	0.851	7.103
8-Jul-99	22:15	1.100	0.020	3.360	0.805	6.382
8-Jul-99	22:30	1.120	0.100	3.460	0.828	6.736
8-Jul-99	22:45	1.150	0.000	3.460	0.863	7.292
8-Jul-99	23:00	1.100	0.000	3.460	0.805	6.382

Table 4. The above table is a small portion of the files converting discharge from the stage data using the rating curve formula, Y = (1.3017 Ln(x)+0.6809). X = stage. Y = log of measured discharge. Discharge = 10^Y. Columns, level/ft = X; log q = Y; Calc. Disch./cfs = 10^Y.

Precipitation data was placed alongside the calculated discharge data within the Excel® data tables, in order to identify and isolate storm events during the study period. These storms reveal characteristics of the watershed, such as, lag time for different parts of the basin, how the soils of the area affect stream response and vegetation as applies to seasonal changes. These characteristics of the watershed were applied to ArcView®, PrePro[6] and Hydrologic Engineering Center- Hydrologic Modeling System (HEC-HMS) to develop a watershed model.

[6] PrePro was developed at the Center for Research in Water Resources at the University of Texas-Austin by Francisco Olivera. It is an add-in program and becomes an integral part of ESRI ArcView®.

ESRI ArcView®

ArcView® was used to gather and manipulate differing 'themes' or parameters of the watershed using the UTM zone 16 coordinate system. These parameters were added to ArcView® file formats as coverages or shapefiles. The 'themes' include landuse, soils, contours/elevations, sections, named roads and section boundaries. Portage County platmap boundaries were digitized by hand, cleaned and errors corrected for the study area and added as another theme. The Moses Creek Watershed was delineated using a USGS digital raster graphic (DRG) of the watershed and added as a theme in ArcView®. A theme delineating the streambed of Moses Creek was added from the DRG. The watershed was also delineated on a hard copy USGS topographic map of the Stevens Point area.

The supplemental program, PrePro, from the Center for Research in Water Resources (CRWR) at the University of Texas at Austin, was incorporated to prepare the ArcView® themes. The preparation started with a Digital Elevation Model (DEM) of that part of Portage County that included the Moses Creek Watershed. Once initiated PrePro becomes embedded in ArcView® as an add-in program and carries ArcView® apr files. The apr files are used to build new PrePro projects within ArcView®.

The first theme added within PrePro was a topographic grid file from the Portage County DEM. A stream arc shapefile was added of Moses Creek and the 'DEM' and 'stream' are combined with a 'burn' command within PrePro. 'Fill sinks' is performed along with 'flow direction' and 'flow accumulation' operations. Using these new themes, new 'stream definitions' were produced by changing the 'stream threshold'. A final 'stream grid' theme was the result. Outlets are linked to the project through an 'outlet grid' and gauge stations and reservoirs were added as shapefiles. Subwatersheds were selected and delineated from the emerging watershed basin.

The raster based streams and watershed were converted to vector base by using the 'vectorize streams and watershed' command. From these, polygon and line shapefile themes were produced of the stream and the watershed. PrePro developed numerous subwatersheds within Moses Creek and these were merged into nine subwatersheds to make the entire watershed more manageable. The subwatershed polygons were selected and 'clipped' to produce a complete watershed.

An attribute table supplied with PrePro was adjusted to fit the parameters of the Moses Creek Watershed by using the previously built themes. A basin schematic was created using transfer tables provided by PrePro. The basin schematic was imported into HEC-HMS and a working model of the Moses Creek Watershed was created (Figure 9).

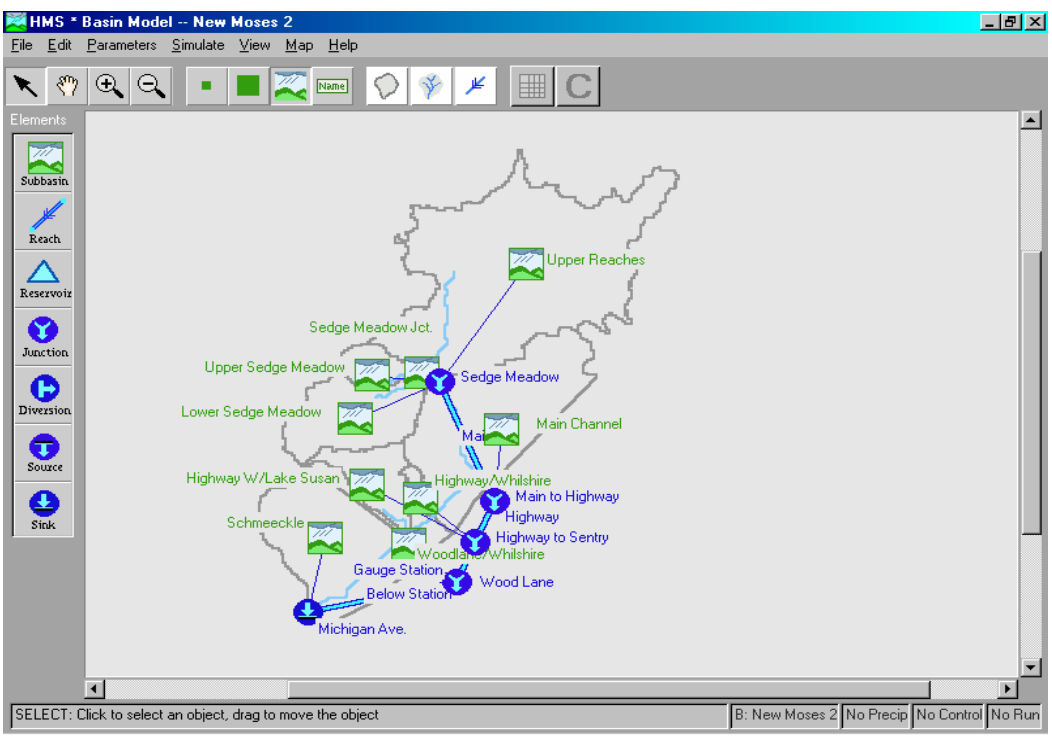


Figure 9. The working schematic of Moses Creek Watershed showing subwatersheds, junctions, reaches and outlet.

ArcView® was used to determine an SCS curve number for each subwatershed for the Moses Creek basin. The Portage County landuse coverage was clipped based on the subwatershed exterior boundary. Percentage of landuse for each subwatershed was found through a tables query. An SCS curve number was assigned to each landuse (LU) based on the curve number tables in the HEC-HMS Technical Reference Manual, Appendix B copied from the SCS report- TR55. A composite curve number for each subwatershed was found using the formula; Composite CN = Sum (%LU * CN / 100). This composite CN was checked using a second formula; Composite CN = Sum (LU area * CN / Total Area of subwatershed)(Table 5). The composite curve numbers were added to the parameter list within HEC-HMS. Excel® spreadsheets illustrating the development of the composite curve number can be found in Appendix A on CD.

The SCS-CN is a function of the hydrologic soil group; cover type/vegetation, treatment/landuse, hydrologic condition, antecedent runoff condition and impervious area (USACE 1999). The purpose of these factors is to determine how easily rainfall will or will not run off of the landscape and into nearby streams or rivers. The USDA-Soil Conservation Service (SCS), now the Natural Resources Conservation Service (NRCS) report TR-55, mentioned above, provides tables for determining the curve number. Curve Numbers range from 30-100, the lower the CN the better the landscape conditions. Conditions indicative of low CN are; a well-canopied woods with considerable litter on the forest floor on sandy soils or lawns, parks, golf courses etc. with greater than 75% grass cover on sandy soils. Conditions with a high CN would be; pastures and grassland used for grazing on heavy clay soils or parking lots, streets, driveways, roofs, etc.

	Highway_Lake Susan subwatershed				
SUM_LU_AREA	LAND_USE	%_LU	SCS_CN	Area*CN	
sq. meters					
27527.0000	Residential	3.14	51.00	1403877	
40357.0000	Roads	4.61	83.00	3349631	% impervious
12142.0000	Utilities	1.39	81.00	983502	Residential
88218.0000	Deciduous Forest	10.07	30.00	2646540	Roads
14416.0000	Coniferous Forest	1.65	30.00	432480	Utilites
405806.0000	Mixed Forest	46.34	30.00	12174180	Water
141336.0000	Water	16.14	100.00	14133600	25.28
75658.0000	Grass and Brush	8.64	35.00	2648030	
62106.0000	Agriculture	7.09	67.00	4161102	% pervious
8135.0000	Recreation	0.93	49.00	398615	All other LU
875701.0000	Total Area	100.00	0.00	42331557	74.72
	Composite CN = Sum Area*CN/Total Area			**48.34019488**	

Table 5. Development of the composite SCS Curve Number (CN), using percentages of each landuse (LU), within the Highway/Lake Susan subwatershed. Standard CN derived from HEC-HMS Technical Reference Manual, Appendix B copied from the SCS report- TR55. Composite Curve Number = Sum %LU*CN/100. Tables for all subwatershed composite CNs within the Moses Creek basin can be found in Appendix A on CD.

3.) *Evaluate different hydrologic modeling software to find the one best suited to the Moses Creek basin.*

Several modeling programs were examined to determine their suitability for this project and the Moses Creek Watershed. These models are: HEC-1, AGNPS/ANN-AGNPS, SWMM, SWAT, SMADA, GWLF and HEC-HMS. Each of these models were evaluated and analyzed based on their working features, usability, and appropriateness for the Moses Creek Watershed. The pros and cons of the models are indicated in the Table 6. HEC-HMS was chosen because it is Windows based. It carries many tools with which to manipulate the data and the watershed characteristics, has the ability to incorporate major attribute (ArcView® and PrePro) data and files, and is supported by the

United States Army Corps of Engineers (USACE)[7]. Although data entry was tedious, once in the system it is easily edited and managed.

	HEC-1	AGNPS/ANN-AGNPS	SWMM	SWAT	SMADA	GWLF	HEC-HMS
DOS	X	X				X	
WINDOWS			X	X	X		**X**
URBAN USE			X		X		
SMALL WATERSHED/ RURAL USE	X	X		X		X	**X**
SEDIMENTATIO N/ LOADING		X				X	
LARGE WATERSHEDS				X			
EASE OF OPERATION				X	X		**X**
ABILITY TO USE ARCVIEW®							**X**
USACE SUPPORT							**X**

Table 6. Evaluation of modeling software. HEC-HMS was chosen because of being; Windows based, worked well in a small rural/urban environment, the user interface learning curve was reasonable, ArcView® themes and tables were appropriate accompaniments to the HMS program and support was provided from USACE (United States Army Corps of Engineers).

4.) *Calibrate the model to the Moses Creek data providing a realistic representation of the watershed.*

HEC-HMS has three essential components needed to facilitate program operation. These are; a basin model, a meteorologic model and control specifications.

The basin model was developed within ArcView® and PrePro and imported into HMS. The model included the delineated watershed and subbasins. Within HMS, stream channel, outlets, reservoirs, stream reaches, and sinks were defined by placing icons

[7] USACE support was helpful during initial setup of the HEC-HMS program and development of the Moses Creek project. They provided e-mail and telephone support while getting the program operational.

(subbasin or junction) within the basin schematic and linking them downstream using the reach icon (Figure 9 p33).

The meteorologic model was developed within HMS. The hand-entered data included, the precipitation and calculated discharge information for specific months during the study period that surrounded the most intense and interesting storms (Appendices B & C). Data can be entered for several different precipitation or discharge gauges. For this project the rain gauge installed on the roof of the Schmeeckle Reserve Visitor Center and the gauging station on Moses Creek where the Green Circle Trail intersects Moses Creek were used. Hand-entered data was checked and edited to eliminate entry errors. Storm events were isolated for theoretical modeling. Five storms revealed themselves as of particular interest and were used to describe Moses Creek Watershed characteristics. These storms are; September 26, 1998, May 22, 1999, July 8, 1999, July 13, 1999 and September 26, 1999.

Control specification data identifies storm periods and time-step information for calculation of the HMS model. Storm periods are separated by a start and stop time and a start and stop date.

Using the run configuration screen, model components are chosen, a name given to the run and a description can be added (Figure 10). With the appropriate components selected (basin model, i.e. New Moses; meteorologic model, i.e. New Schmeeckle; control specifications, i.e. 8Jul1999), a model 'run' can be initiated. Basin model, meteorological model and control specifications can be reordered and combined in different ways to build different 'runs'. Within the run manager screen, different runs can be chosen to do a 'compute/simulation (Figure 11 p39). A 'run' produces a modeled discharge output for the model components, thus, a modeled hydrograph can be compared with a specific storm hydrograph. Model parameters can be adjusted to improve the modeled hydrograph.

These parameters were used to set-up the model (Table 7). The SCS-Curve Number (CN) is described as a function of hydrologic and landscape conditions. Initial Abstraction (IA), is the amount of precipitation removed from the landscape by vegetation or absorbed by the soil and not available as runoff. Lag Time (LAG), the time between a rainfall event and the recording of discharge increases. Percent Impervious Cover (% IMPERVIOUS), the portion of the landscape yielding runoff without any IA. Each of these parameters is variable and can be adjusted within the model to fit Moses Creek's characteristics (Table 7).

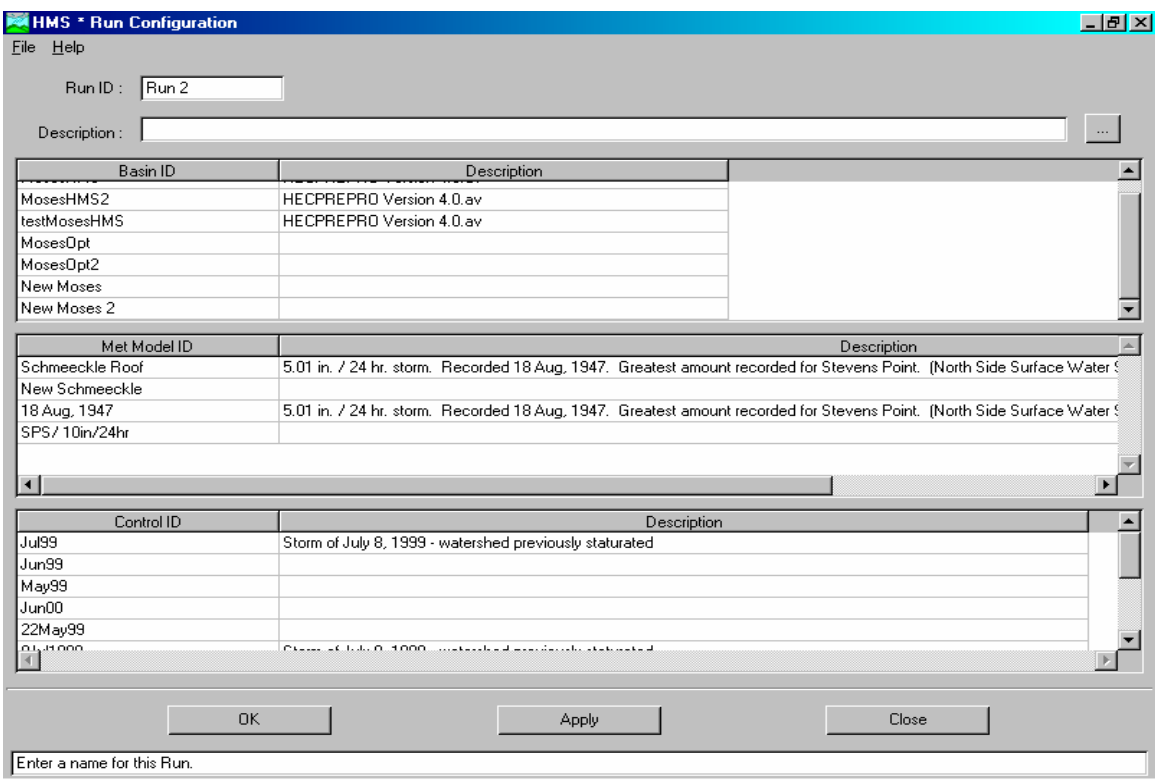


Figure 10. A view of the run configuration window within HMS. Model components can be selected, named and described to create different runs. Runs are stored in the run manager.

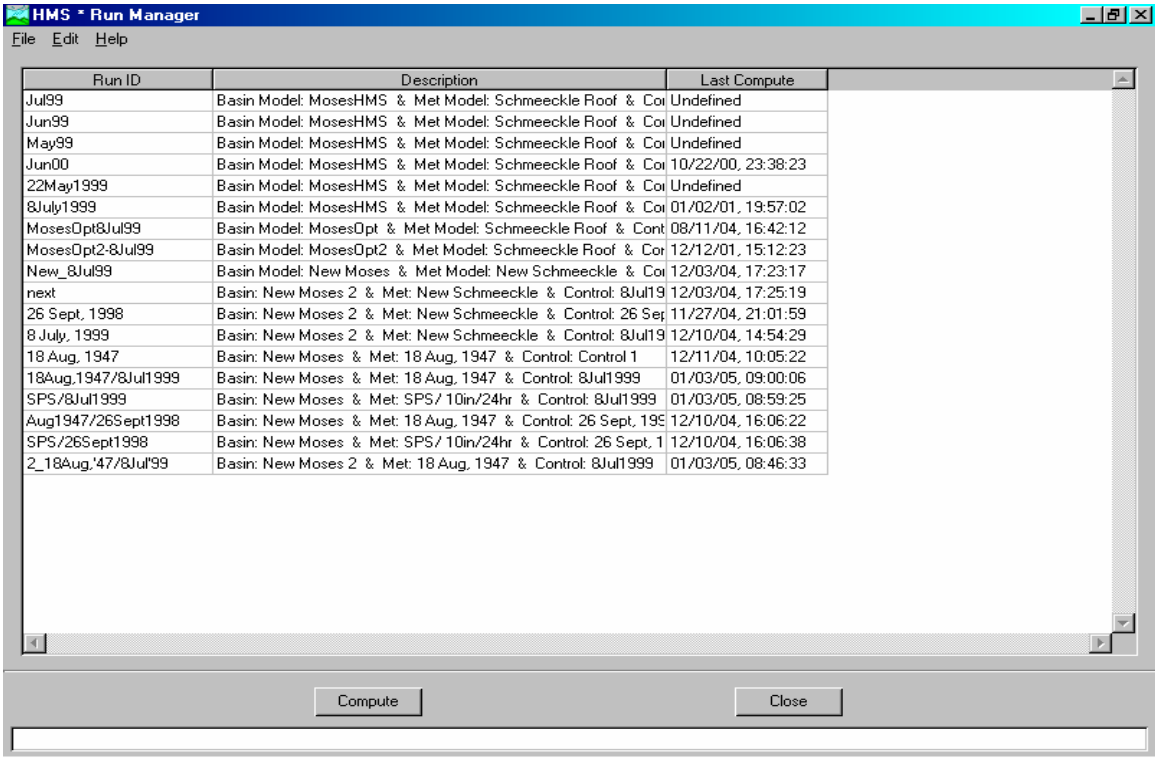


Figure 11. A view of the run manager window within HMS. Runs are selected for simulation and compute can be initiated from here or on the basin schematic window.

	IA-1 Inches	CN–1	LAG-1 Minutes	% IMPERVIOUS
Wood Lane/Wilshire	2.5	46.82	8.0	46.79
Highway/Lake Susan	2.25	48.34	65.0	25.28
Highway/Wilshire	2.25	49.29	12.0	20.33
Main Channel	3.25	39.14	660.0	28.35
Upper Reaches	2.5	45.86	1000.0	15.49
Upper Sedge Meadow	4.5	31.76	840.0	0.58
Sedge Meadow Jct.	4.0	33.71	840.0	0.00
Lower Sedge Meadow	3.5	38.44	840.0	5.44
IA-1 - Derived from *Hydrology* (Wanielista, 1997), Table 5.6 p.155.				
CN-1 – Composite Curve Number using formula – Composite CN = Sum(%LU *CN / 100).				
LAG-1 – Initial estimated lag time based on watershed characteristics.				
% IMPERVIOUS - % impervious cover at initial model setup, developed from % landuse of each subbasin that reflects imperviousness (roads, airports, commercial, institutional, water, etc).				

Table 7. Moses Creek Subwatershed initial parameters for HEC-HMS

When computed discharge reflects the observed discharge as closely as possible, the ‘optimization function’ of HMS is incorporated to further improve the results. The HMS optimization tool incorporates several user specified search methods and several user specified objective function equations. The search methods can be described as the process by which modeled parameters are adjusted to produce an optimal fit between a modeled hydrograph and an observed hydrograph. HEC-HMS has two methods for adjusting the selected parameters to obtain an optimal fit (USACE 1998). With the Univariate Gradient method, adjusting the value of an individually selected parameter while all other parameter values are held constant minimizes the objective function. The Nelder and Mead method is based conceptually on constructing a polyhedron (simplex) in dimensional space. The simplex expands and contract as its vertices are moved through space until the objective function value reaches a minimum. The Nelder and Mead method changes the magnitude of all selected parameters with each iteration (USACE 1998). The objective function equations are a measure of the goodness of fit of a computed hydrograph compared to an observed hydrograph (USACE 1998).

	IA-1 Inches	**IA-2 Inches**	CN–1	CN-2	LAG-1 Minutes	**LAG-2 Minutes**	% IMPERVIOUS
Wood Lane/Wilshire	2.5	**0.02**	**46.82**	57.0	8.0	**5.33**	46.79
Highway/Lake Susan	2.25	**0.02**	**48.34**	58.0	65.0	**111.93**	25.28
Highway/Wilshire	2.25	**0.02**	**49.29**	59.0	12.0	**31.73**	20.33
Main Channel	3.25	**0.05**	**39.14**	49.0	660.0	**569.71**	28.35
Upper Reaches	2.5	**0.05**	**45.86**	56.0	1000.0	**1149.67**	15.49
Upper Sedge Meadow	4.5	**0.05**	**31.76**	42.0	840.0	**244.97**	0.58
Sedge Meadow Jct.	4.0	**0.05**	**33.71**	44.0	840.0	**234.33**	0.00
Lower Sedge Meadow	3.5	**0.05**	**38.44**	48.0	840.0	**502.30**	5.44

IA-1 - Derived from *Hydrology* (Wanielista, 1997), Table 5.6 p.155.
IA-2 - Adjusted IA for best fit to produce best-compared hydrographs.
CN-1 -Composite Curve Number using formula – Composite CN = Sum(%LU*CN/100).
CN-2 – Curve Number adjusted to reflect possible future charges within the watershed. Increased housing, increased impervious cover, decreased vegetative cover, etc.
LAG-1 – Initial estimated lag time.
LAG-2 – Adjusted LAG for best fit to produce best-compared hydrographs.
% IMPERVIOUS - % impervious cover at initial model setup, developed from % landuse of each subbasin that reflects imperviousness (roads, airports, commercial, institutional, water, etc). Changes in imperviousness are included in changes in curve number, CN-2.

Table 8. Moses Creek Subwatershed initial and **optimized parameters** for HEC-HMS

The lower the objective function value the better the fit. After numerous optimization runs, the Univariate Gradient search method and peak-weighted RMS error objective function were chosen because the modeled results they produced more closely matched the observed discharge of the Moses Creek Watershed. Numerous adjustment 'trials' were made to obtain the desired results. Final optimized parameters are shown in Table 8, together with initial parameter values.

5.) *Use the model to estimate the effects future urbanization may have within the Moses Creek watershed.*

Once the model was calibrated to produce discharge results that reflected those of the observed discharge of Moses Creek, the HMS program could be manipulated to reflect the results of changes in watershed parameters. For instance, since development would effectively reduce basin retention, one possible method of reflecting change in the basin would be to increase the SCS-Curve Number (CN). The CN is a function of the hydrologic conditions of an area represented. The curve number, CN, will be described more fully later.

Raising the SCS-CN within the model will effectively change several watershed characters simultaneously. These changes are; an increase in impervious cover, a decrease in vegetative cover and, indirectly, a decrease in lag time. Thus, resulting in changes in hydraulic response. In order to describe theoretical response, first, observed response needs to be discussed.

Several storm events were isolated from the study data. These events were used to illustrate response. Lag times of differing proportions can be explained through consideration of watershed characteristics such as impervious cover, soil type, antecedent moisture, or distance from monitoring station. All of the selected storms were analyzed and modeled. The storm giving the best model response was used to evaluate the response of the model to changes in landuse, to reflect future urban development within the watershed. The same optimized model was used to test the model with extreme storm events, to reflect the result of catastrophic rainfall.

To test the model, two additional storms events were incorporated into the model. The first storm was found in ‘North Side Surface Water Study, City of Stevens Point, Wisconsin (Donohue 1980). This storm represents the most intense storm reported to us in Stevens Point, 5.01 inches in 24 hour. on August 18, 1947. The second storm was a Standard Project Storm (SPS) derived from a theoretical model found in Appendix A of the HEC-HMS Hydrologic Modeling System Technical Reference Manual (July 1999) obtained from the USACE EM1110-2-1411. The ‘SPS Index Rainfall’ chart indicates that a 10-inch/24 hour storm is possible within the Moses Creek Watershed.

RESULTS/DISCUSSION

Basin Response Analysis

The Moses Creek Watershed is small and seemingly insignificant, but study of the data gathered reveals many interesting characteristics about the watershed. Standard characters such as, increased imperviousness and structural drainage improvements (Bost 1980) and loss of wetlands (Hey 1995) that can and will increase runoff and flooding were expected. But, Moses Creek also reveals several unique habits. Storms isolated from the spreadsheet data were examined to determine Moses Creek’s characteristics.

The first of these storms is that of September 26, 1998 (Figure 12). The initial conditions of the watershed are dry and drying. Vegetation is mature and has reached the end of the growing season and beginning the process of senescence. The time since the last storm is significant enough that Moses Creek is dry/no flow. This storm has a

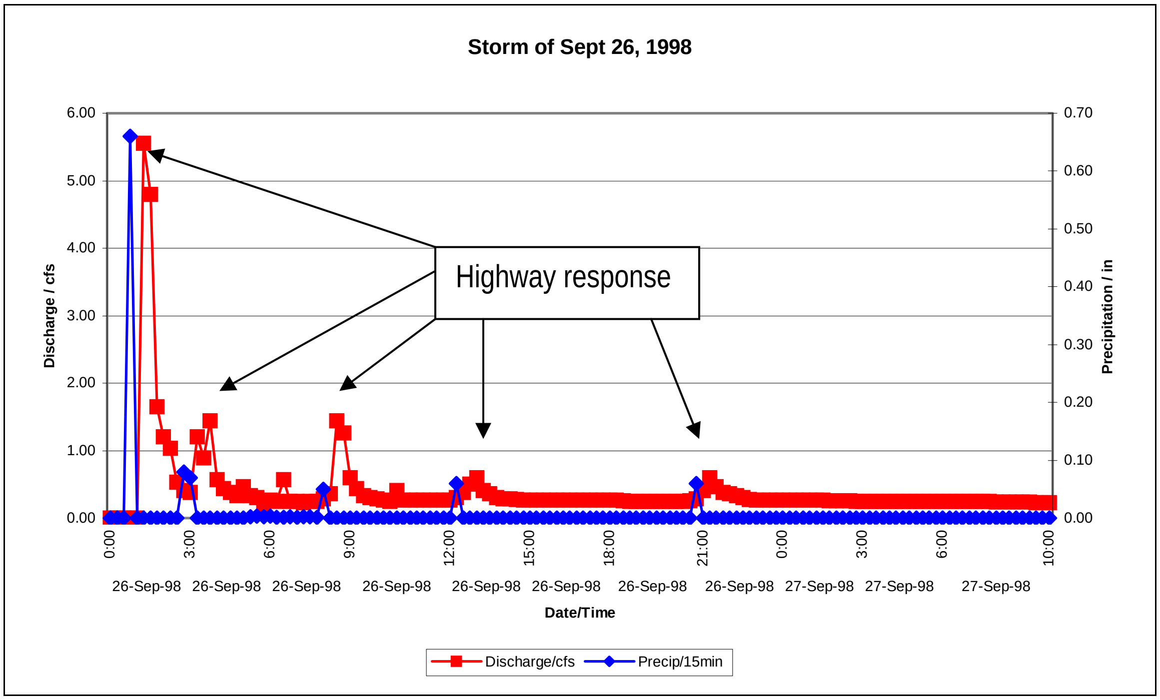


Figure 12. Graph of the September 26, 1998 storm. Discharge in red and precipitation in blue.

total duration of about 20 hours with a total precipitation amount of 1.00 inch. The initial rainfall amount was 0.66 inch, with several lesser rainfall amounts throughout the storm. Discharge peaks closely mirror each of the precipitation peaks. The lag time in this event is 15-30 minutes. The very short lag time is likely due to the Highway 39/51 crossing Moses Creek about 300 yards upstream from the installed measuring station. The impervious pavement of the roadway and the compacted ditch areas funnel runoff directly into Moses Creek. Since this is a four-lane divided highway, the area in question here is significant. The immediate area is approximately 40 acres. The intensity of the rainfall is positively correlated to the discharge peaks. During the rain event, the direct runoff from the roadway gathers in the ditches and culverts, is channeled into the stream, and reaches the field station in 15-30 minutes. This is confirmed by each of the precipitation peaks throughout the storm, and will be seen again with other storms. After rainfall stops, stream discharge quickly returns to baseflow. At this time of year, baseflow can be near or at zero discharge.

The next storm (May 22, 1999) occurs under different conditions (Figure 13). Occurring in May, when vegetation is near full growth potential, much moisture is being used through evapotranspiration. The initial part of this hydrograph is in its recession phase; it is decreasing toward baseflow. At the time of the rainfall event, there is a burst of precipitation of 0.13 inch followed by several smaller bursts providing a total of 0.36 inch of rain. This happened at a point on the hydrograph that would have appeared to be another drop in discharge; instead the discharge levels off and continues level for more than two days. This may be caused by the fact that the last rain of significance before this event was 5 days earlier and only 0.33 inch. This rain, too, was a small amount, lending to the assumption that the watershed is drying or somewhat drying at this time. The highway ditches were probably dry enough to absorb the rainfall without sending a peak downstream. The length of the level discharge is likely due to slow sustained discharge from the sedge meadow upstream from the highway. The sedge meadow will be more important in other storms. After enough drying has occurred within the watershed the hydrograph continues its recession.

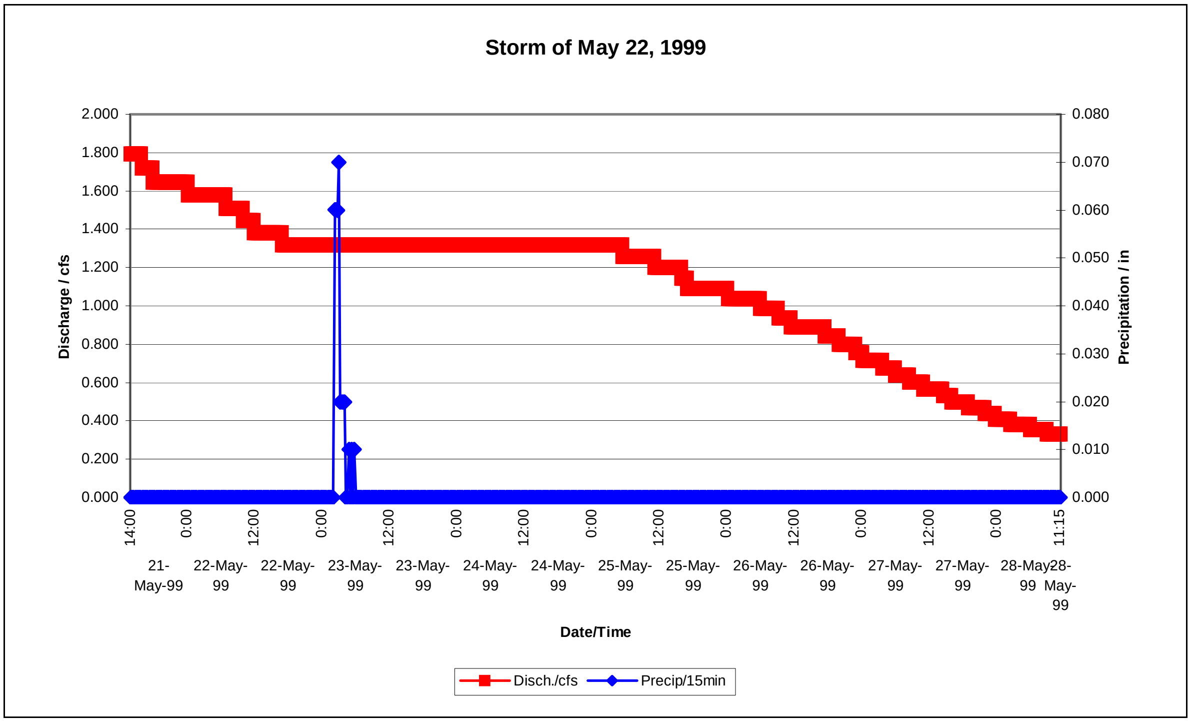


Figure 13. Graph of the May 22, 1999 storm. Discharge in blue and precipitation in red.

Conditions are changing further in the storm of July 8, 1999 (Figure 14 p.47). Vegetation is in full growth, similar to the May 22 storm, but this time the watershed is saturated. There has been 3.0 inches of rain in the last ten days. This storm alone brings an additional 1.78-inches of rain in only three hours. Regardless of these differences, the watershed is responding similarly to the way it did to the September 26, 1998 storm and the May 22, 1999 storm, and adding something new as well. First the hydrograph shows a baseflow condition at the onset of the storm. A peak in discharge closely follows an initial burst of rain at 15-30 minutes. This can be seen at the start of the storm and again about an hour later. The graph then continues recession until about 12 hours after the storm. At this time there is a major increase in discharge with no associated rainfall. This can be explained by looking at the sedge meadow. The sedge meadow acts as a sponge until it becomes full and must empty itself downstream. The associated lag time, with the draining of the sedge meadow, is about 12 hours. The peak in the discharge at the 12-hour lag time shows two peaks. If we look at the rainfall event at the beginning of the storm we see that there are two rainfall peaks in close order. The double peak at the sedge meadow is in agreement with the rainfall peaks. Interestingly, there is another event to observe during this storm. At about 8:00 PM on July 9 there is a small rain event, only 0.02 inch, yet the graph of the recession curve flattens just as the highway runoff enters the flow, 15-30 minutes after the rain, similar to the May 22 storm, indicating a surge from the highway. Also, there is a tiny increase in the recession curve at the 12-hour lag time for the sedge meadow. This small, almost insignificant, rain amount reveals a stream response similar to the large 1.78-inch storm. This is likely happening because the watershed is at or near saturation. Following the storm, Moses Creek returns to its baseflow condition.

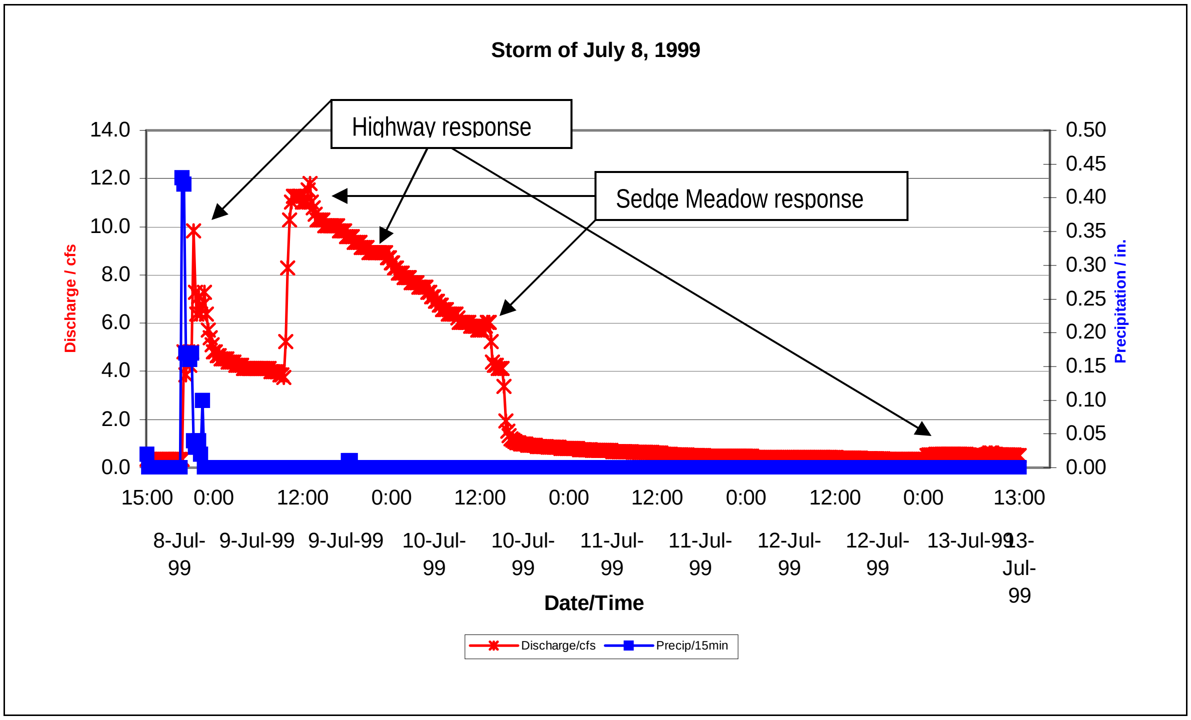


Figure 14. Graph of the July 8, 1999 storm. Discharge is in red, precipitation is in blue.

A storm on July 13, 1999 (Figure 15) shows a similar response to that of the 0.02-inch portion of the July 8 storm. A seemingly insignificant amount of rainfall still reveals these watershed characteristics, a fast/flashy response from the highway and a slow delayed response from the sedge meadow.

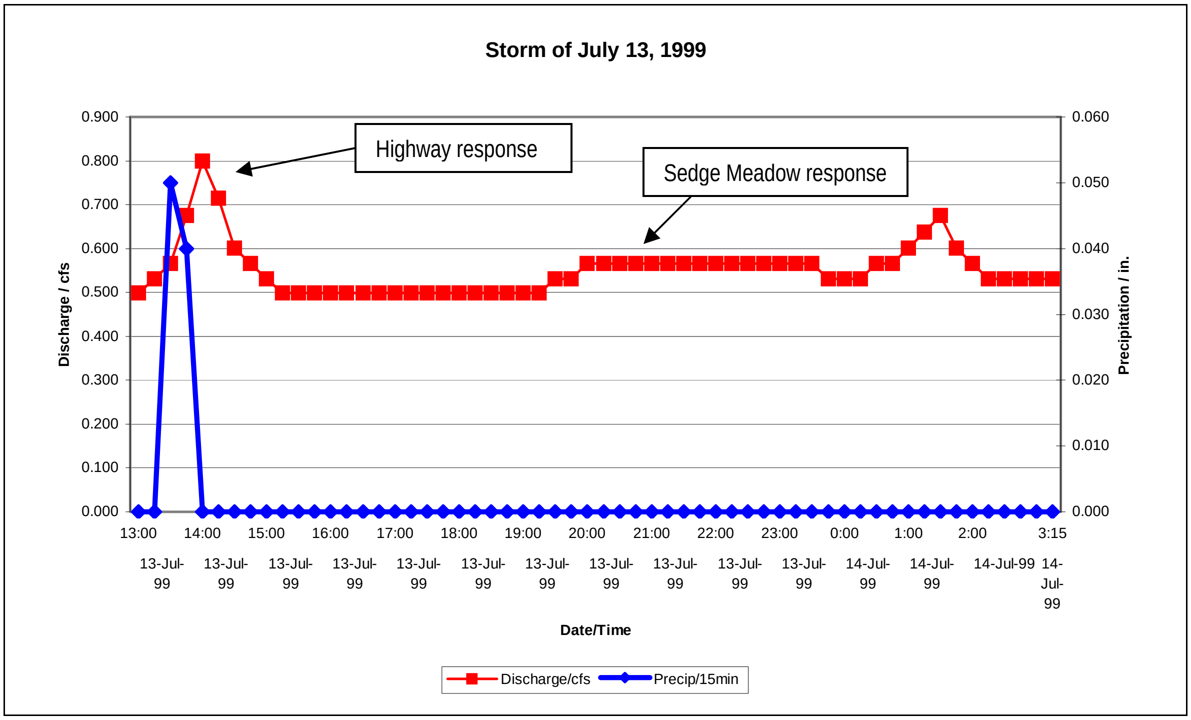


Figure 15. Graph of the July 13, 1999 storm. Discharge is in red, precipitation is in blue.

The last storm to be discussed will be different from the other storms. This event occurred September 26, 1999 (Figure 16).

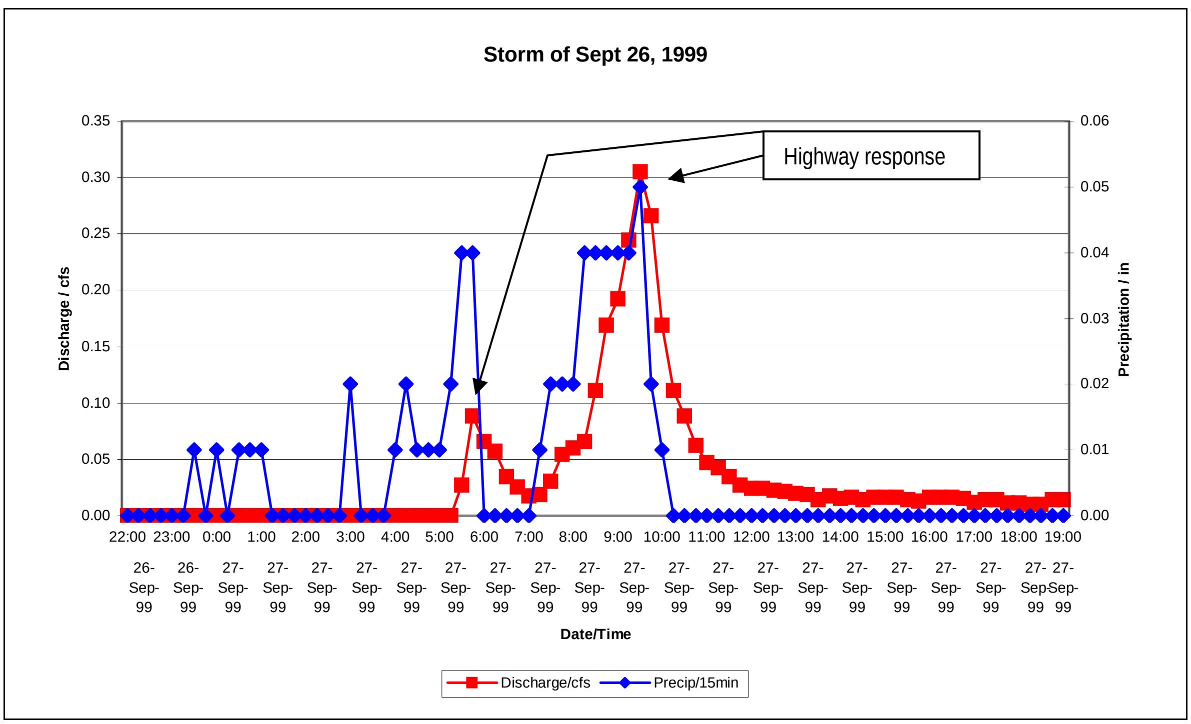


Figure 16. Graph of the September 26, 1999 storm. Discharge is in red and precipitation is in blue.

Vegetation is beginning to die back for the year. Rain for the month thus far has been 0.39 inch, and Moses Creek is dry. The onset of precipitation does not bring a measurable response from the highway. The ditches are dry, as is the streambed; it takes time to absorb enough moisture to initiate flow. Rainfall of 0.2 inch is needed to produce any flow. Yet, even under these extreme conditions when flow does start the response is similar to other storms within the watershed. A discharge peak closely follows a precipitation peak. This storm event occurs over an extended time of 10.75 hours. The low rainfall amounts early in the storm are needed to saturate the areas surrounding the stream before any flow can be initiated. Once the rain stops the hydrograph quickly returns to baseflow and a no flow condition.

Discussion of selected storms

Moses Creek is easily affected by minor changes within the watershed. The watershed is sandy and dries quickly requiring substantial wetting before a response is initiated. Yet, when saturated, even a fractional amount of precipitation can produce measurable results. The vegetative cover of the area can also produce effective responses. As plants enter full leaf stage more moisture is used to maintain evapotranspiration, thus slowing lag times. Once senescence occurs, lag time decreases.

One important feature of the watershed is the crossing of Interstate 39/U.S. Highway 51. The highway crossing is about 300 yards upstream from the gauging station. Although this subwatershed of the highway is small, the very high imperviousness of the area has a dramatic impact on data gathered at the station. The lag time from the highway is short, 15-30 minutes. The storm hydrograph at the station has a very abrupt rising limb and an equally abrupt recession limb. Physical evidence of this phenomenon can be acknowledged in the discovery of pieces of the expansion material from between highway pavement sections found at and downstream from the gauging station. Worked loose from the highway by changing weather conditions or traffic, the flashiness of this portion of the watershed carried these pieces quickly downstream. Also, while on a data collecting field trip, in an attempt to gather stream gauge data before a storm, I witnessed an 8-10 inch rise in stage of the stream in a twenty-minute period. Further upstream the lag time produced from the sedge meadow at the headwater area of the watershed is very different from that of the highway area.

The sedge meadow acts like a sponge, holding storm flow for 12-15 hours before becoming saturated enough to send its load downstream. The vegetation throughout the sedge meadow and downstream also act to slow flow. This factor is indicated in the second peak in the hydrograph from the monitoring station. There is a long slow rising limb with a significantly higher discharge with a long, slow recession limb following peak discharge.

During small summer showers that occurred after an extended period of dryness there were instances when the stream did not respond at all. The sandy soils, in the streambed and immediately adjacent to the stream, become dry enough to increase the initial abstraction beyond that of the rainfall of the shower. Further upstream, initial interception and evapotranspiration keep flow to a minimum after small showers during the dry summer months.

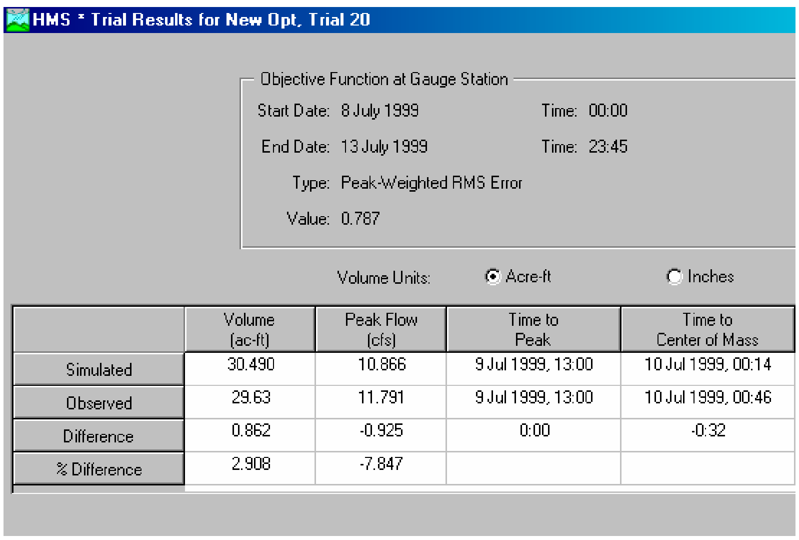
The highway, being close to the monitoring station, also plays a dramatic role in the stream response. While the sedge meadow invokes a much larger discharge response it is also buffered by time. Dunne and Black, indicated that many subtle variables would change discharge hydrographs. While they primarily focused on subsurface contributions to storm flows, Moses Creek hydrographs react similarly through subtle surface characteristics (Dunne and Black 1970).

What affect might these simple characteristics of the Moses Creek Watershed have on the immediate area? Due to the dynamic of the nearby imperviousness Moses Creek could flood with little if no warning and in fact has flooded parts of Stevens Point in the past. How will these known dynamics help to predict future flow regimes of the creek? Changes in the percentage of impervious cover, especially near the streambed, will affect the way in which the sedge meadow can buffer rainfall events (Dunne 1982). Bost, further emphasizes that increasing impervious cover increases runoff rates, produces higher flood peaks, and shorter lag times (Bost 1980).

Modeling Results

The previously discussed storms expose Moses Creek as it relates to the current conditions within the watershed. Each storm demonstrated differing characters of the watershed and nuances of the model. The July 8, 1999 storm produced the best model results because the conditions of Moses Creek surrounding the storm closely approximate those of a perennial stream, while the other events of the study showed little or no baseflow at the time of the storm event because they are ephemeral. While documentation on the model does not expressly mention this fact, it seems likely that HEC-HMS as well as many or most other modeling programs are built around perennial flow events. The July 8, 1999 storm and optimized parameters became the design storm for the Moses Creek Watershed model.

The modeled July 8, 1999 storm when compared to the observed discharge showed less than 3% difference in volume, less than 8% difference in peak flow, zero difference in time to peak and a 32 minute difference in time to center of mass. The objective function value was below 0.8 (Figure 17). Low objective function values are better than high values. The remaining four storms under consideration also had low objective function values when optimized.



	Volume (ac-ft)	Peak Flow (cfs)	Time to Peak	Time to Center of Mass
Simulated	30.490	10.866	9 Jul 1999, 13:00	10 Jul 1999, 00:14
Observed	29.63	11.791	9 Jul 1999, 13:00	10 Jul 1999, 00:46
Difference	0.862	-0.925	0:00	-0:32
% Difference	2.908	-7.847		

Figure 17. Trial results for the July 8, 1999 storm with optimized parameters.

The modeled hydrograph for the storm closely matches the observed hydrograph (Figure 18). After successful optimization, the model was modified to test the effects of changes within the watershed. In this case, the SCS-CN and Initial Abstraction were changed to produce a so-called moderately extreme scenario. The SCS-CN was increased by ten on the CN scale within each of the subwatersheds in the basin (Table 9). Initial Abstraction was decreased by 0.01-0.025 inches. The CN is a function of the hydrologic conditions of an area represented. Being one of the hydrologic conditions of the CN, if land use of the area changes, then the CN would change. The better the hydrologic

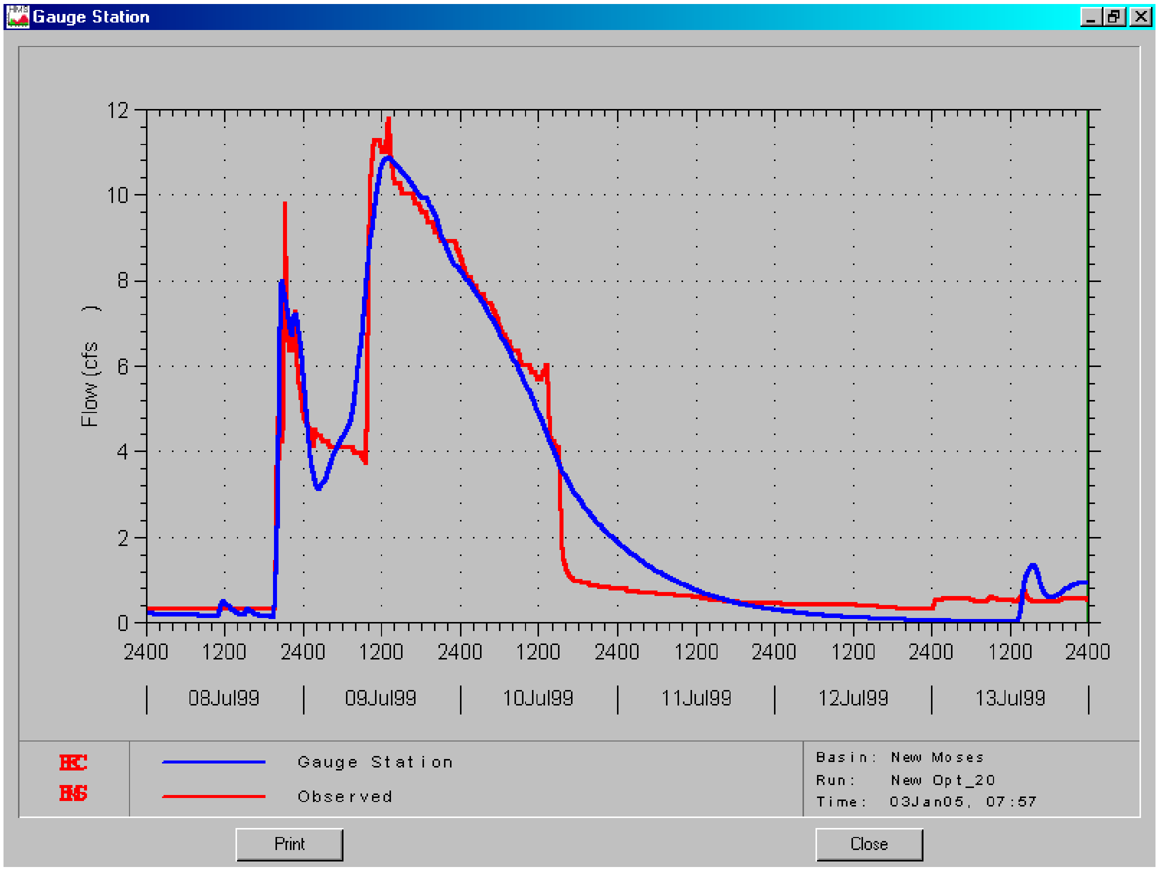


Figure 18. Hydrograph of the modeled (blue, gauge station) and observed (red) discharge from the July 8, 1999 storm.

conditions, the lower the CN. A wooded area of 20 acres, with good canopy and ground cover on sandy soil, has a CN of 30 and 0% impervious cover. The same 20 acres, with ten two-acre lots, has a CN of 46 and is 12% impervious. Make that 20 acres into a trailer park, and the CN is 61 with 38% impervious. Turn that area into a Wal-Mart® parking lot, and the CN is 98 and nearly 100% impervious. Initial Abstraction is inversely proportional with the CN, as CN goes up, IA goes down. This means with an increase in CN there is less likelihood of rainfall being captured in the landscape before runoff occurs. Now back to the CN and IA adjustments within the model. The CN was increased by 10, to reflect a moderate change throughout the entire Moses Creek basin. In actuality, some of the subwatersheds may not have an increase in CN, while others may have large increases. Likewise actual changes in IA may not be uniform across the entire basin. For testing, the changes will reflect accurately the response of Moses Creek.

	IA-1 Inches	IA-2 Inches	*CN–1*	CN-2	LAG-1 Minutes	LAG-2 Minutes	% IMPERVIOUS
Wood Lane/Wilshire	2.5	0.02	46.82	**57.0**	8.0	5.33	46.79
Highway/Lake Susan	2.25	0.02	48.34	**58.0**	65.0	111.93	25.28
Highway/Wilshire	2.25	0.02	49.29	**59.0**	12.0	31.73	20.33
Main Channel	3.25	0.05	39.14	**49.0**	660.0	569.71	28.35
Upper Reaches	2.5	0.05	45.86	**56.0**	1000.0	1149.67	15.49
Upper Sedge Meadow	4.5	0.05	31.76	**42.0**	840.0	244.97	0.58
Sedge Meadow Jct.	4.0	0.05	33.71	**44.0**	840.0	234.33	0.00
Lower Sedge Meadow	3.5	0.05	38.44	**48.0**	840.0	502.30	5.44

IA-1 - Derived from *Hydrology* (Wanielista, 1997), Table 5.6 p.155.
IA-2 - Adjusted IA for best fit to produce best-compared hydrographs.
CN-1 -Composite Curve Number using formula – Composite CN = Sum(%LU*CN/100).
CN-2 – Curve Number adjusted to reflect possible future charges within the watershed. Increased housing, increased impervious cover, decreased vegetative cover, etc.
LAG-1 – Initial estimated lag time.
LAG-2 – Adjusted LAG for best fit to produce best-compared hydrographs.
% IMPERVIOUS - % impervious cover at initial model setup, developed from % landuse of each subbasin that reflects imperviousness (roads, airports, commercial, institutional, water, etc). Changes in imperviousness are included in changes in curve number, CN-2.

Table 9. Moses Creek Subwatershed initial and optimized parameters for HEC-HMS

The resulting hydrograph showed a dramatic change in the modeled discharge (Figure 19). The changes observed with the SCS-CN increase and IA decrease continue to reflect the basic response characteristics of the watershed.

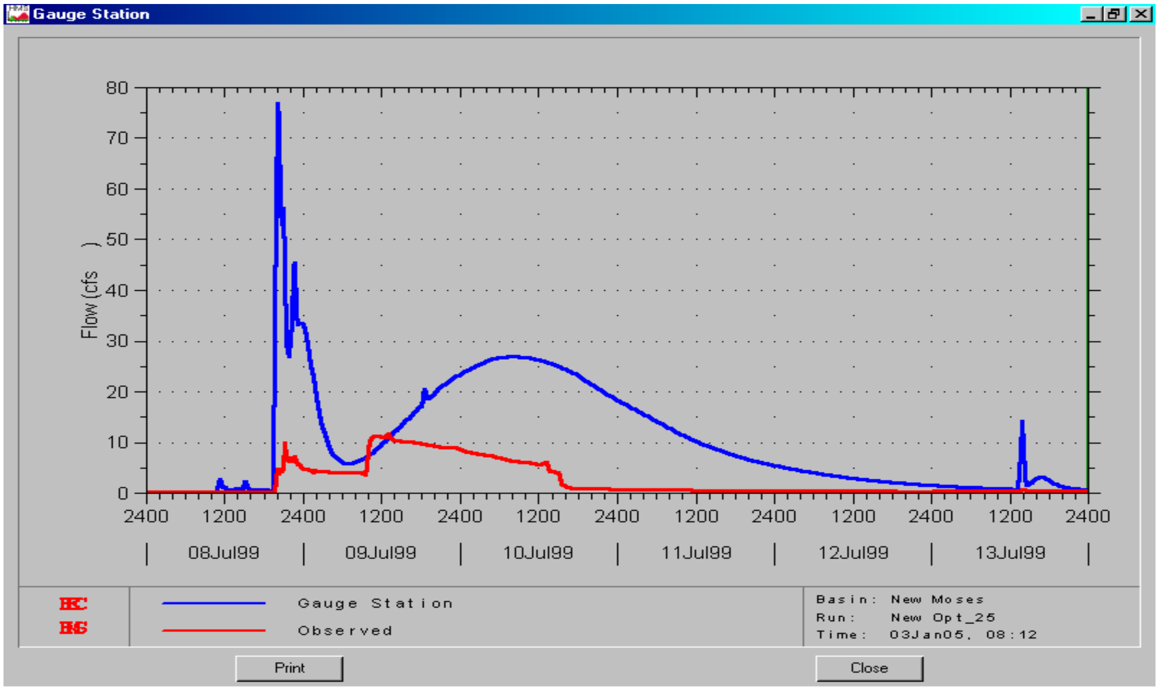


Figure 19. Hydrograph showing an increase in SCS-CN and a decrease in IA. The hydrograph of the July 8, 1999 storm used as comparison. The July storm (observed) is graphed in red and the modeled (gauge station) hydrograph is blue.

Peaks and recessions are near the appropriate times when compared with the July 8, 1999 hydrograph. The modeled hydrograph also shows an immediate peak from the highway and a long, slow recession curve from the sedge meadow.

The July 8, 1999 storm produced a discharge of 12 cfs from a rainfall of less than 2.8 inches. The modeled output, with the changed parameters (moderate change scenario), produced a discharge of 76 cfs, more than six times that of the observed storm. The same rainfall generated more outflow, simply from a change in the number of houses (i.e. impervious surfaces). This suggests that change of any type within the watershed would cause dramatic results upon the downstream area of Moses Creek. Even precipitation effects that are normal today could result in more damage. What type of trade-offs are acceptable? If a new Target® or Applebee's® goes into place along Highway 66, whose basement is going to be under water after the next rain? With the future rerouting of U.S. Highway 10, could the highway through Moses Creek become six-lanes? What would the flash discharge from that highway be? Or maybe holes on the SentryWorld® golf course will be too wet to play. Are there storms recorded or possible that may have an even larger impact upon the watershed?

The parameters of the watershed for the two test storms were returned to previously modeled conditions. SCS-CN were set to the derived composite CN for each subwatershed and the initial abstraction was set to the textbook dimensions (Wanielista 1997). The storm of August 18, 1947 (5.01 inch/24hour) when modeled within Moses Creek produced a hydrograph with a peak discharge of 117 cfs (Figure 20). This is nearly a factor of ten in the magnitude of the discharge over the observed July 8, 1999 storm. This was modeled using current watershed conditions; the only difference was the larger storm of 1947.

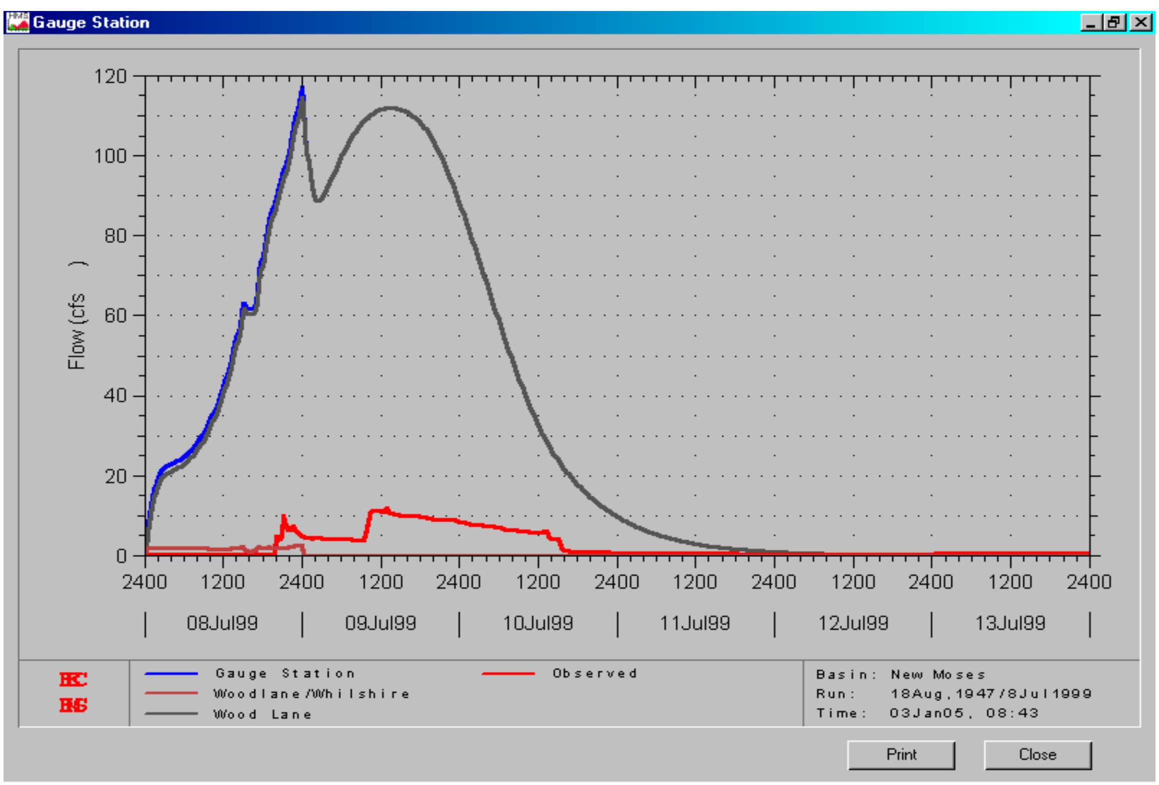


Figure 20. Hydrograph for the modeled (gauge station is in blue) August 18, 1947 storm. The July 8, 1999 storm (observed is in red) is used for comparison.

The characteristics of the Moses Creek Watershed continue to be evident, one discharge peak for the highway and one for the sedge meadow.

The Standard Project Storm (SPS) determined from the USACE EM1110-2-1411(USACE 1999), produced an even greater discharge (Figure 21). This is expected since this is a 10inch/24hour storm. The characteristics of the Moses Creek Watershed are still evident even in this extreme situation. Double peaks are produced at the appropriate times to mirror the highway and the sedge meadow. The magnitude of the discharge from this storm is 35 times greater than the July 8, 1999 storm. Using the developed rating curve and the height of the Green Circle Trail Bridge, runoff would likely begin lifting the bridge at about 300 cfs, that is, assuming the stream stays in its prescribed channel.

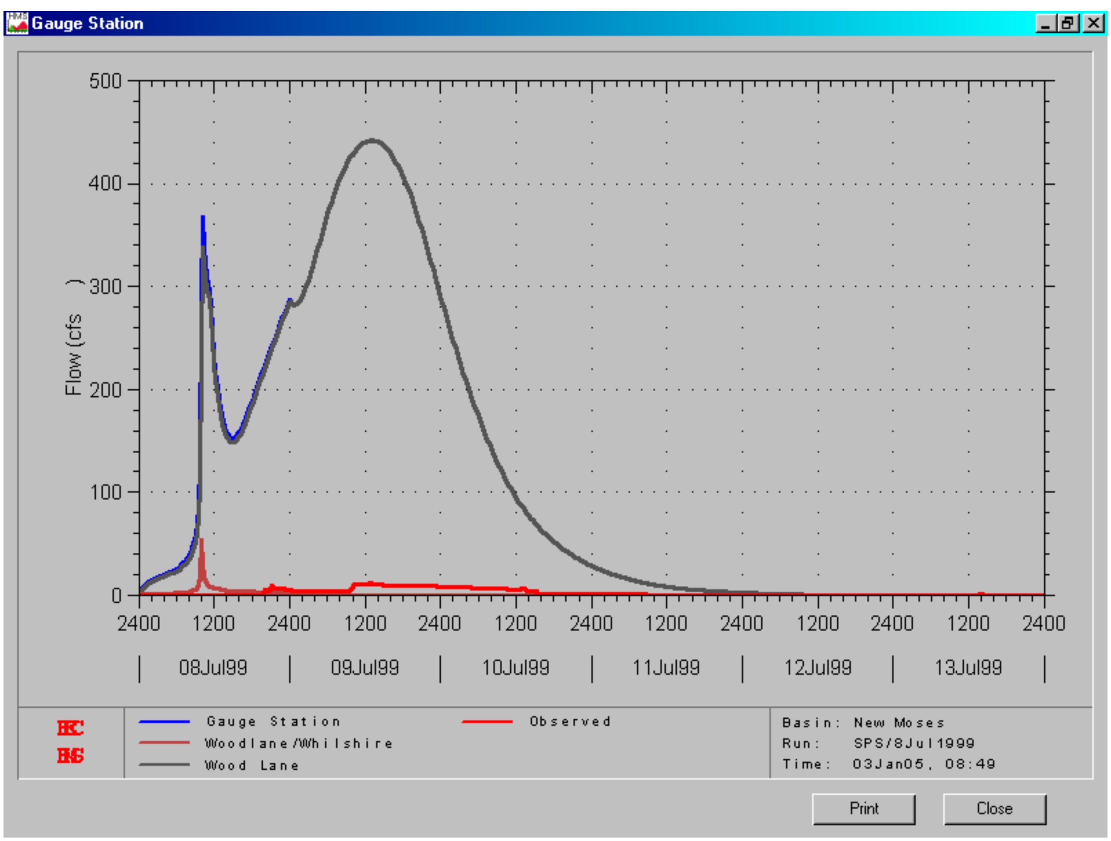


Figure 21. Hydrograph of the SPS 10in./24hr. storm. The July 8, 1999 (observed in red) storm used as comparison. The modeled hydrograph (gauge station) is in blue.

Well before the Green Circle Bridge floats downstream, Moses Creek would have topped its banks. Personal observation has seen the ditches surrounding Moses Creek full and flowing in the wrong direction at about 60 cfs discharge at the gauging station. The 60 cfs discharge was observed during the July 8, 1999 storm.

Keep in mind, both of these test storms were modeled using current conditions for the watershed. When a rainfall event occurs, similar to the magnitude of the August 1947 or SPS storms, flooding will overwhelm the infrastructure of Moses Creek and the City of Stevens Point storm sewer system.

These storms represent extreme circumstances. A storm similar to that of August 18, 1947 has not occurred in 57 years. A 10inch/24hour SPS storm may never happen, however, storms of this scale are possible. If impervious cover continues to grow in the watershed, discharges of this nature are easily attainable.

Data collected for this study, when analyzed, passed the test of regression analysis and provided observed hydrographs of the watershed. Entered data allowed the HEC-HMS program to produce an 'optimized' model that provided a representative view of the watershed. The model worked well to demonstrate the characteristics of Moses Creek and can be trusted to illustrate future scenarios surrounding the watershed.

Possible Improvements to Prevent Future Flood Events and Improve Monitoring Events

To reduce the potential for downstream flooding, the sedge meadow needs to be protected from encroachment by development. Downstream, the re-creation of wetland areas along Moses Creek will provide additional buffers during peak flows. Buffer areas between Highway 39/51 and the stream entrance to the city storm sewer at Michigan

Avenue would be of high value. These buffers would capture and slow part of the flash discharge from Highway 39/51. Meanders placed within the stream itself would slow flow downstream.

This study could have been improved with the addition of one, or more monitoring stations placed in or near the sedge meadow. This would substantiate flow from the sedge meadow and validate lag times between the meadow and the monitoring station at the Green Circle Trail Bridge. Placement of rain gauges in the sedge meadow would provide further evidence of positive relationships between rainfall and discharge. The use of additional rain gauges and stream monitoring stations would allow the watershed to be divided into more precise subwatersheds. These new subwatersheds would then allow more detailed analysis of the Moses Creek characteristics.

Outside of a catastrophic event on the Wisconsin River, it is also clear that Moses Creek is likely the single most influential environmental feature in Stevens Point related to flood events. City planners and leaders should therefore be wary of expanding urbanization the Moses Creek Watershed and its likely effects on runoff. It is hoped that this study will aid in future decisions concerning the expansion of the City of Stevens Point.

LITERATURE CITED

Bost, Richard C., Phillip B. Bedient, Peter G. Rowe. "Effect of urbanization on alternative flood control strategies." Water Resources Bulletin. 16(4) (1980): 710-716.

Chow, Ven T. Handbook of Applied Hydrology. New York. McGraw-Hill. 1964. p.8:43-50.

Donohue and Associates. "North side surface water study." City of Stevens Point, Wisconsin. 1980. p.1-28.

Dunne, Thomas. "Models of Runoff Processes and Their Significance." Scientific Basis of Water Resource Management. National Research Council. Geophysics Study Committee. (Study in Geophysics series). Washington D.C. National Academy Press. 1982. p.17-30.

Dunne, Thomas, Richard D. Black. "Partial Area Contributions to Storm Runoff in a Small New England Watershed." Water Resources Research. 6(3) (1970): 1296-1311.

Eggers, Steven D., Donald M. Reed. Wetland Plants and Plant Communities of Minnesota and Wisconsin. St. Paul. U.S. Army Corps of Engineers. 1997. p.86-104.

Feldman, Arlen D., Darryl W. Davis. "Recent HEC modeling activities." In-Proceedings of the Federal Interagency workshop on hydrologic modeling demands for the 90's. 1993. p.1-30.

Franklin, Marvin A. “Methodology for stormwater runoff investigation, Urban Leon County, Florida.” U.S. Geological Survey. Open-File Report 82-355. 1982. p.1-15.

Hey, Donald L., Nancy S. Philippi. “Flood reduction through wetland restoration: The upper Mississippi River basin as a case history.” Restoration Ecology. 3(1) (1995): 4-17.

Holt, C. L. R. Jr. Geology and Water Resources of Portage County Wisconsin. Geological Survey Water-Supply Paper 1796. Washington. U.S. Government Printing Office. 1965. p.1-7.

Maidment, David R., ed. Handbook of Hydrology. New York. McGraw-Hill. 1993. p.8.23-8.26.

Mitsch, William J., James G. Gosselink. Wetlands. 2nd edition. New York. Van Nostrand Reinhold. 1993. p.577-615.

Needham, Scott E., Robert A. Young. “ANN-AGNPS: A continuous simulation watershed model.” In- Proceedings of the Federal Interagency workshop on hydrologic modeling demands for the 90’s. 1993. p.4-32.

Pabst, Arthur F. “HEC’s next generation software project.” In- Proceedings of the Federal Interagency workshop on hydrologic modeling demands for the 90’s. 1993. p.6-26.

Sherwood, James M. “Estimation of volume-duration-frequency relations of ungauged small urban streams in Ohio.” Water Resources Bulletin. 30(2) (1994): 261-269.

Spirn, Anne Whiston. "Designing with the land." Journal of Soil and Water Conservation. 47(1) (1992): 35-38.

U. S. Army Corps of Engineers – Hydrologic Engineering Center. HEC-HMS – Technical Reference Manual. Hydrologic Engineering Center. Davis, California. 1999.

U. S. Army Corps of Engineers – Hydrologic Engineering Center. HEC-HMS – Hydrologic Modeling System – User's Manual, version 1.0. Davis, California.Hydrologic. Engineering Center. 1998.

U. S. Army Corps of Engineers – Hydrologic Engineering Center. HEC-1 - Flood Hydrograph Package – User's manual, version 4.0. Davis, California. Hydrologic Engineering Center. 1990.

U. S. Department of Agriculture Soil Conservation Service (Natural Resources Conservation Service). Soil Survey of Portage County, Wisconsin. Madison. Research Division of the College Agricultural and Life Science. University of Wisconsin. 1978.

U.S. Geological Survey. Flood-frequency and detention-storage characteristics of Bear Branch watershed. Murfreesboro, Tennessee. Water-Resources Investigations Report 96-4005. 1996. p.10-14.

Wanielista, Martin, Robert Kersten, Ron Eaglin. Hydrology- Water Quantity and Quality Control. 2nd edition. New York. John Wiley and Sons. 1997 p.153-160.

Winston, Richard B. "Design of an urban, ground-water-dominated wetland." Wetlands. 16(4) (1996): 524-531.