DOCUMENTATION AND ANALYSIS OF FLASH FLOOD PRONE STREAMS AND SUBWATERSHED BASINS IN PULASKI COUNTY, VIRGINIA

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ABSTRACT

Flash flooding is the number one weather-related killer in the United States. With so many deaths related to this type of severe weather, additional detailed information about local streams and creeks could help forecasters issue more accurate and precise warnings, which could help save lives. Using GIS software, streams within twenty-five feet of a roadway in Pulaski County, Virginia were identified and selected to be surveyed. Field work at each survey point involved taking measurements to determine the required stream level rise necessary to cause flooding along any nearby roadway(s). Additionally, digital pictures were taken to document the environment upstream and downstream at each survey point. This information has been color-coded, mapped, and overlaid in Google Earth for quick access on computers at the National Weather Service Office in Blacksburg, Virginia. It has also been compiled into an operational handbook and DVD for use at the NWS.

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INTRODUCTION

Research Purpose

Intense rainfall over a small watershed basin can cause local streams and creeks to rise quickly and produce flash flooding. If there are nearby roadways, rising water levels in these waterways can cause bridges and culverts to become inundated and overflow, prompting a need for closure. To better understand which locations along certain roads are most likely to be impacted by flash flooding, research and field work must be conducted to determine how high water in nearby streams must rise to cause flooding. The objectives of this research project include:

- Identify and fully document road locations in Pulaski County, Virginia that are prone to flash flooding from nearby streams by calculating the stream's flood stage.
- Compile finalized data and maps in digital form onto DVD as well as in paper form in an operational handbook.
- Create an overlay in Google Earth with all available data that can be accessible from workstations at the National Weather Service.
- Basins within the county will be mapped as a GIS overlay for use in Gibson Ridge's radar-viewing software, GRLevel3. Additionally, surveyed points measured along each basin's main-stem stream/creek will also be included in the overlay. *To be completed after the report distribution date.*
- <u>Overall purpose</u>: Provide the NWS with detailed information about Pulaski County's streams and their flood stage(s) relative to nearby roadways, with the main goal of helping forecasters issue more accurate and precise flash flood warnings over the county.

Background Information

The National Weather Service (NWS) Weather Forecast Office (WFO) in Blacksburg, Virginia is responsible for issuing forecasts and warnings for 40 counties and 11 independent cities in Southwest Virginia, Northwest North Carolina, and Southeast West Virginia. The County Warning Area (CWA) is geographically diverse, from mountainous terrain in the west to rolling hills and piedmont in the east. Numerous types of severe weather throughout the year make forecasting a challenge across this area. Flooding, specifically flash flooding, is of major concern since it is the nation's number one weather-related killer (NWS, 1992). It has occurred in all 40 counties of the WFO Blacksburg CWA and climatological maximums occur during June with minimum occurrences in October and December (Stonefield et al. 2009). According to the NWS and their Storm Data Preparation article (NWS, 2007), flash flooding is defined by:

Whenever one or more of the following occur within six hours or less during a causative event such as intense rainfall, dam break, or an ice jam formation:

- River or stream flows out of its banks and is a threat to life or property.
- Person or vehicle is swept away by flowing water from runoff that inundates adjacent grounds.
- A maintained county or state road is closed by high water.
- $\geq$6 inches (15 cm) of fast-flowing water cover a road or bridge. This includes low-water crossings in a heavy rain event that is more than localized and poses a threat to life or property.
- Any amount of water in contact with, flowing into, or causing damage to a residence or public building as a result of above ground runoff from adjacent areas.

- ≥3 feet (.9 m) of ponded water that poses a threat to life or property.
- Mud or rock slide caused by rainfall.
- Flood waters containing a minimal amount of debris (mud, rock, vegetation) caused by rainfall. This could possibly occur in a burned area with only light to moderate rainfall.

Pulaski County, Virginia was chosen for this research project because of its close proximity to Virginia Tech and its familiarity to the author/primary investigator. The county is situated in the ridge and valley region of the Appalachian Mountains in Southwest Virginia and the county seat, Pulaski, is approximately 40 miles (64 km) west-southwest of Roanoke, Virginia. The county covers 330 square miles (855 km^2), of which 9 square miles (23 km^2) are water in the form of Claytor Lake. As of the 2000 U.S. Census, Pulaski County has a population of 35,127 bringing the population density to 109 people per square mile (42 per km^2) (U.S. Census Bureau, 2000). In addition to the Town of Pulaski, the Town of Dublin and a number of smaller communities are located in the county (Figure 1).

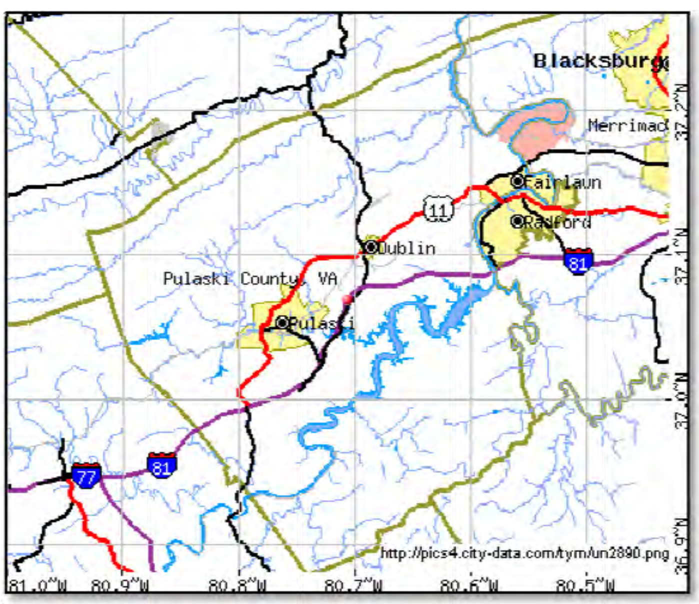

Figure 1. Map of Pulaski County, VA.

It is important to point out that any county or local area could be a focus for this type of research. This would be at the discretion of NWS officials or county administrators and would likely focus on counties that are highly susceptible to small-stream flash flooding. This will be discussed in the section *Recommendations for Future Research*.

Similar Research

In early 2009, similar research was published for the Springfield, Missouri NWS WFO. The Flash Flood Risk Analysis Project (FFRAP), coordinated by Mr. Andy Foster, successfully mapped and categorized basins, streams, and communities by their flood threat across the entire CWA. This information was also passed on to emergency management officials in Missouri. Geographic and physical characteristics of the area were analyzed using GIS and included such data as: basin slope, soil statistics, vegetation/forest cover, and land use. Social and economic information also was also incorporated into the research and included: road use statistics, rate of flood occurrence, and population density per county (Foster, 2009). Although much of the same data was collected for the current research project (road use and soil statistics, basin slope, land use, etc.), there are several additional elements that make this project unique. These additional components will be evident throughout this report.

DATA AND METHODOLOGY

Constructing the Research Project

Several visits were made in early June to the Blacksburg WFO to determine what additional information would be useful to operational forecasters during flash flood events. With only two months of funding available from Virginia Tech, this put a constraint on what type of research could be conducted and any work done in the field would need to be limited to 14 days or less. Once it was determined that Pulaski County would be the focus for additional flash flood research, both officials at the NWS and the author decided that photographing and measuring streams within the county would be an important contribution to the WFO. This would include measuring the flood stage along county roads where a stream passes within 25 feet. In this report, "flood stage" refers to "the required height water would have to rise in a stream or creek to cause flooding of the nearby roadway." In addition to the flood stage measurement, an upstream and downstream picture would be taken at each surveyed point to visually document the surrounding landscape. Additionally, the author also met with the Emergency Manager of Pulaski County to gather and coordinate data, as well as gain approval of the research. Flash flood and soil statistics in GIS form were also collected from Pulaski's Information Technology (IT) Officer. Individual subwatershed basins in the county would be mapped with the latest aerial photography and each map would be overlaid with information collected from the field. Furthermore, an additional page or two would be attached to the basin maps and would contain tabular data regarding land cover and use, soil characteristics, and previous flash flood reports for that particular basin. The basins used for this project were obtained from the NWS by email and are the exact basins projected in the Advanced Weather Interactive Processing System (AWIPS) and the Flash Flood Monitoring and Prediction (FFMP) program. The basin polygons, in the form of shapefiles, were imported into ArcGIS for projection and analysis. ArcGIS is a software suite that consists of different programs used to map, analyze, and store geographic and spatial information. Two programs within ArcGIS, ArcMap and ArcCatalog, were used extensively for this project in mapping and analyzing collected data. The sections below on methodology will attempt to explain how each map was created and how specific information was obtained for each basin. Before any analysis and mapping could be done, survey points had to be identified and flood stage data had to be collected.

Identifying Survey Points

Road and stream networks in Pulaski County were required to be mapped to determine the locations where a stream passes within 25 feet of a named road. Data from the United States Census Bureau was downloaded in the form of 2007 TIGER/Line shapefiles and then imported into ArcMap. Since the basins provided by the NWS do not follow political boundaries, it was necessary to download road and stream shapefiles for surrounding counties as well, including: Bland, Wythe, Carroll, Floyd, and Montgomery, as well as the City of Radford. This will also be true for data such as land use and soil statistics for all basins extending beyond Pulaski County.

Within ArcMap, a basic query by attributes was conducted to select line data where "HYDROFLG" = 'Y'. This query selected only those lines listed by the U.S. Census Bureau as streams, creeks, or rivers. These hydrolines were then exported as a new shapefile named *streams*. Another attribute query, "ROADFLG" = 'Y', was also performed to select all roads, which were then exported as *roads*. Next, the attribute list for the new *roads* shapefile was opened and sorted by "FULLNAME". Only those roads with a description listed under

"FULLNAME" were selected and re-exported as *named roads*. The two shapefiles, *streams* and *named roads*, provided the spatial data needed to determine where a stream passes within 25 feet of a named road. A new query was conducted to select features by their location. Features were selected from the shapefile *named roads* wherever they were within 25 feet of the features in the shapefile *streams*. This was then exported as a new shapefile, *roadpoints*. However, this new shapefile was not in the form of point data, so each area that was identified had to be plotted and mapped by creating a new shapefile in ArcCatalog named *points*. This shapefile was then opened in ArcMap and editing turned on to allow points to be created manually wherever the shapefile *roadpoints* identified road areas that were within 25 feet of a stream. This took considerable time, and in the end, 651 points were identified. This represents all locations within Pulaski County where a named road is within 25 feet of a stream or creek.

Preparing for Data Collection

Once all known survey locations were identified and mapped for Pulaski County, it was necessary to subdivide the county into smaller, workable sections. These sections would encompass nearly 60 survey points each but would have no affect on the outcome of the research. Their sole purpose was to help manage how many points were surveyed each day, making sure that all points within each section were within travel distance for that particular day. With nearly 60 surveys to be completed each day, it was required to create each section around existing road networks to aid in the logistics of completing each section within eight to ten hours. For example, if a section were created that crossed Claytor Lake, then it would take an additional 30 to 60 minutes to reach the required survey points on the other side. There is only one major road crossing which is located at Lowman's Ferry Bridge and this would require extra travel time. Therefore, each section was created to allow all the points within that section to be surveyed within eight to ten hours. A total of 12 sections were created, each taking one day to complete, and two days off for the weekend after the first week.

The tools needed for field work included:

- Canon PowerShot S3 IS Digital Camera
- Suunto Tandem Clinometer
- Empire 100’ Open Reel Fiberglass Tape Measure
- Laptop computer with GPS (used in-car for navigation)
- Data sheets, clipboard, and pens

By running ArcMap in the vehicle, along with an active GPS position, navigating about the county was extremely easy. The GPS function within ArcMap plots current location, along with all the survey points and county roads and streams. It will also store a “bread-crumb” trail which will allow for a quick review of where surveys have already been completed. A log containing the exact roads traveled, by date and time, has been included with the accompanying DVD. A basic Microsoft Excel document was created to help with recording the: object ID, road name, stream name, road type, stream flow, distance from road to stream, angle of depression, point type, and upstream and downstream image IDs. Each of these will be described in detail in the next section. The Excel file was printed on 30 sheets of paper for use in the field and once all preparations were complete, surveying could begin one section at a time.

Data Collection and Field Work

Data collection began each morning around 9 a.m. and was usually complete by 6 p.m. that evening, with a one hour break for lunch each day. At each survey point it would take about five to ten minutes to complete all measurements, take both photographs, and record all data. The object ID for each survey point was verified using ArcMap and was then recorded on the data sheet. Road type information, which refers to the type of road covering, either paved or dirt/gravel, was also documented. The stream flow was listed as either: none, slow, normal, or fast, and was used to record how slow or fast water was flowing at that survey location. The distance from the road to the stream was measured from the author's eye-level to the outer edge of the stream or creek (Figure 2, line "d"). Each measurement was taken to the nearest half-foot. Additionally, the angle of depression was measured using the clinometer from the author's eye-level to the outer edge of the stream (Figure 2, "θ").

Figure 2. The author taking measurements and an overlay of how to calculate flood stage.

These two measurements allow for the calculation of the flood stage for that survey point. Using some basic trigonometry the total height of the right triangle in Figure 2 side "h" can be determined in feet. However, this would calculate how high the water would need to rise to reach the author's eye-level, which is of no value at all. How then is the flood stage (FS) calculated? Knowing that the author is exactly six feet tall from eye-level to the ground, subtract six from the total height of side "h" and the final value is the vertical rise in water needed to reach the roadway and cause flooding. The equation used for this calculation is given as:

$$FS = [d \cdot SIN(\theta°)] - 6$$

The flood stage calculation has a margin of error up to 6" since distance measurements were rounded to the nearest half-foot and since the exact height from the author's eye-level to the ground may have been off two to four inches due to the tilt of the head and back.

Additional information that was collected at each survey point included the survey location type, or road/stream crossing type, which refers to whether the survey was conducted at a bridge (B), culvert (C), low-water crossing (LWC), or alongside a stream running parallel with the road (AS). Finally, the digital camera records a unique ID number for each picture, and this number was recorded on the data sheets to help identify each upstream and downstream picture that was taken.

Each evening, collected data was input into Microsoft Excel and each picture was downloaded and stored. Using the basic trigonometric equation above, Excel was able to calculate the flood stage for each measured point automatically once the distance measurement and angle of depression were known. All field work was completed in less than 12 days, due to several factors. First, only 319 points out of the total 651 were successfully surveyed. The remaining 332 points were either on private roads or did not exist. Furthermore, a couple of the 12 survey sections were completed within the same day, which shorted the total length of field work by one day each.

Orthophotography and Elevation Maps

Once all measurements were complete and all data was entered into Microsoft Excel, the spreadsheet was then imported into ArcMap for analysis. Using the flood stage calculations in feet, each surveyed point was assigned a color-coded scheme using a graduated symbology, as shown below:

Red: <1.5 feet

Orange: 1.5 – 3.0 feet

Yellow: 3.0 – 5.0 feet

Green: 5.0 – 8.0 feet

Turquoise: 8.0 – 12.0 feet

Blue: >12.0 feet

For example, if a certain surveyed point was calculated to have a flood stage of 1.3945 feet, then it would be plotted in ArcMap as a red dot, whereas a surveyed point with a flood stage of 18.1 feet would be identified as a blue dot. This information would then be overlaid on a map for each separate NWS basin (Figure 3).

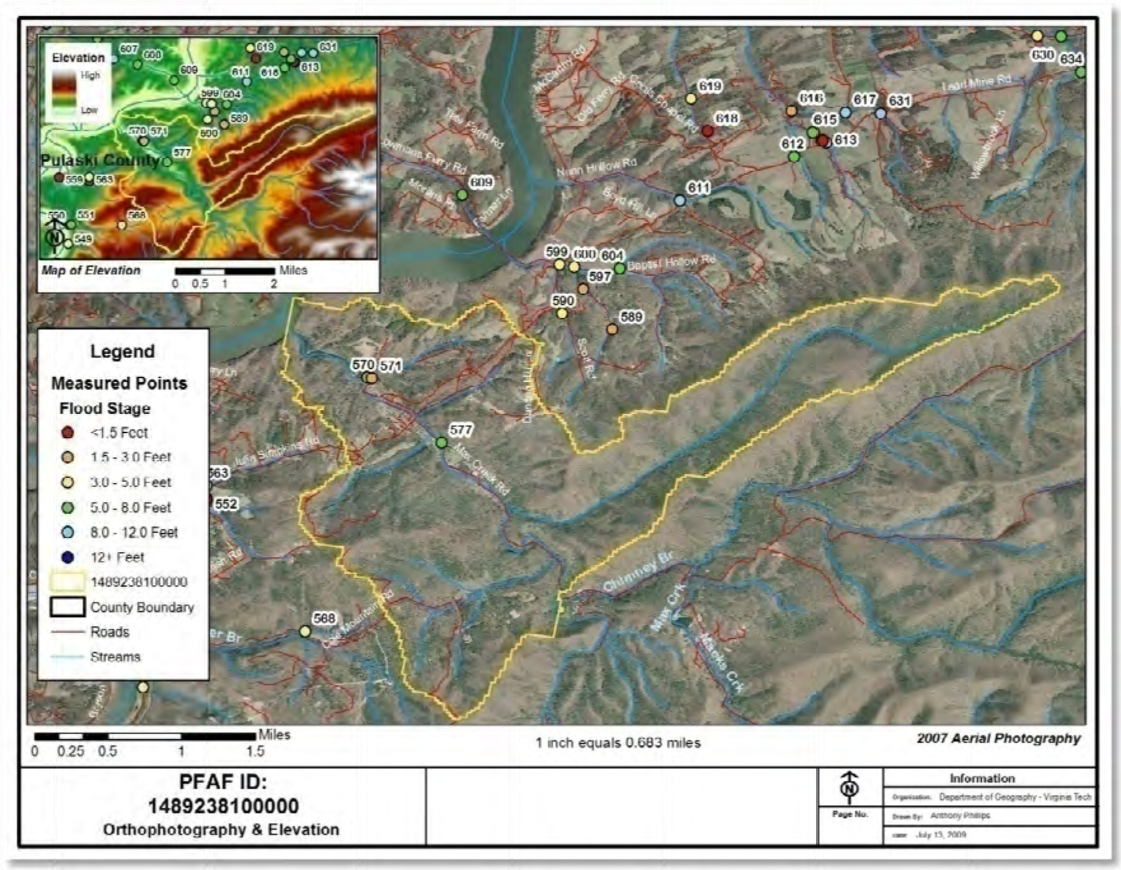

Figure 3. Basin map example with elevation inset and PFAF ID.

Each map outlines an individual basin's boundary, in yellow, and identifies it by its Pfafstetter ID[1]. The Pfafstetter system provides a relationship between a basin of interest and other basins located nearby through a number-coding classification. By knowing the PFAF ID, an individual can then determine the upstream and downstream basins associated with that certain basin of interest. In addition to the surveyed points and basin data included on each map, local roads (both named and unnamed) and streams are also plotted. A small inset map also plots the elevation using Digital Elevation Model (DEM) data for the same area with the basin boundary and surveyed points overlaid.

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[1] Furnanas, J., F. Olivera. *Watershed Topology – The Pfafstetter System*. http://proceedings.esri.com/library/userconf/proc01/professional/papers/pap1008/p1008.htm.

If a forecaster would like to know what information there is about a particular basin, he or she can single-click on individual basins within FFMP and the PFAF ID can be determined. Once a PFAF ID is known, it can then be used to reference the research provided in this report and on the accompanying DVD.

GIS information about previous flash flood reports was also acquired from the NWS office in Blacksburg. If a certain basin has any known reports of flash flooding from the past, then this data is overlaid as point data on an additional attached map of elevation (Figure 4). This will hopefully provide the forecaster with knowledge about where flash flooding has previously occurred and can be used to correlate this research to previous flash flood reports.

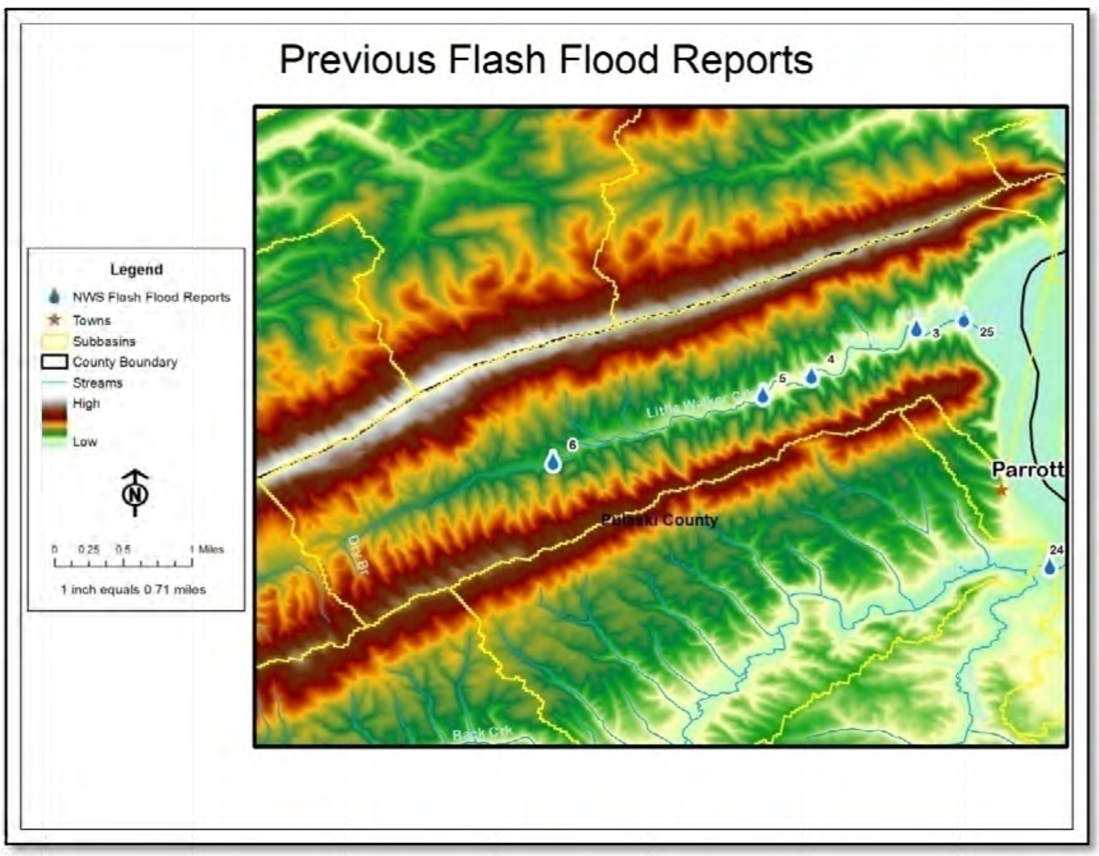

Figure 4. Previous reports of flash flooding for each individual basin.

All 319 surveyed points are documented through 89 different maps attached with this operational handbook as well as on the DVD. These maps represent the bulk of this research project and are considered the go-to reference for determining the flood stage along a certain stream or creek.

Tabular Data

Attached along with each basin map are one to two pages of tabular data (Figure 5). These pages provide information and useful statistics for only the named basin. Land use and land cover, as well as soil statistics, are provided. Additionally, any surveyed points within that basin are listed, along with each point's collected data. Finally, all previous flash flood reports that were received from that particular basin are included in tabular format.

Basin PFAF ID: 1489213200000

Measured Points Information

OBJECTID	Road	Stream	Stream Flow	Road Type	Road/Stream Crossing Type	Upstream Picture ID	Downstream Picture ID	Flood Stage	Number of Vehicles per Day
59	Depot Road	unlisted	normal	dirt	C	IMG-4729	IMG-4730	3.258864	330
63	Blair Road	unlisted	none	dirt	C	IMG-4724	IMG-4725	3.500000	20
68	Holland Road	unlisted	none	paved	C	IMG-4722	IMG-4723	2.000000	1000

*Object IDs highlighted in red are located near the mouth of the basin and are most affected by rainfall over the basin.

Previous NWS Flash Flood Records for Basin (see attached map)

POINT ID	Lat	Lon	Brief Description
23	37.174000	-80.609900	Dry Branch flooded SR 600 (Belspring Rd./Parrot River Rd.)

Land Use/Cover Percents

PFAF_ID	Crops	Water	Pavement	Rooftop	Resid/Indust	Mine	Pine	Mixed Forest	Hardwood	FOREST
1489213200000	69.499	0.293	3.410	0.000	4.406	0.000	6.466	8.605	7.143	22.214

*FOREST column is the sum of Pine, Mixed, and Hardwood columns.

Soil Type Percents

PFAF ID	MUSYM	Soil Area (Square Miles)	Percent Soils within Basin
1489213200000	13B	0.00323	0.174
1489213200000	13C	0.09133	4.937
1489213200000	13D	0.11083	5.991
1489213200000	17	0.03585	1.938
1489213200000	19C	0.00652	0.353

Figure 5. Portion of tabular statistics page for one individual basin.

The table "Measured Points Information" contains data about each point surveyed within that particular basin. In Figure 5 there are three measured points. Each point is listed numerically by its ObjectID and each lists the associated road and stream network where the survey was conducted. Each point also includes information about: stream flow, road type, road/stream crossing type, upstream and downstream picture IDs, flood stage, and road use statistics. Road use information was provided by the Virginia Department of Transportation (VDOT) and measures the average number of vehicles that travel the road listed during a 24-hour period, calculated during the 2007 calendar year[2]. *Note: the Number of Vehicles per Day or the Average Daily Traffic Count Data that reads "0" indicates that 2007 traffic data from VDOT is not available for that road/location.* ObjectIDs that are colored red indicate surveyed points that are along the main-stem stream and located near the mouth of the particular basin. These points may have a higher likelihood of seeing flash flooding due to their location within the basin, but this would depend on the flood stage for those named points and the amount of rain that occurs over the basin.

All previous flash flood reports are listed under the "Previous NWS Flash Flood Records for Basin" table. Any previous flash flood reports that have geographic coordinates within the basin are listed here. Each previous flash flood record was given a unique identifier known as the Point ID, which was used to separate each previous report. The latitude and longitude and a brief description of where the event occurred and any damage or related information is also included.

[2] Virginia Department of Transportation. *2007 Traffic Data*. http://www.virginiadot.org/info/resources/AADT_077_Pulaski_2007.xls.

“Land Use/Cover Percents” is the next table of information provided. This documents land use and forest cover percentages for only the basin listed. For example in Figure 5, basin with PFAF ID: 1489213200000, is composed of 69.5% crops, .3% open water, 3.4% pavement (roads), etc. This information, along with the recent aerial photography, will hopefully provide insight into the composition of the different types of land use and forest cover present. Any basins that have a high percentage of forest cover are not likely to see flash flooding since the vegetation will likely soak up any rainfall that does occur. Likewise, any basin that has a high percentage of farmland and crops would likely have a higher chance of seeing flash floods, due to the lack of deep root systems and open fields. These statistical values were calculated using ArcMap and were limited to the boundaries of each individual subwatershed basin. The Virginia Department of Forestry (VDOF) was the source for GIS data on land use, with the most recent data available conducted in 2005[3].

The final table included is the “Soil Type Percents.” Data for Pulaski County was provided by the Information Technology officer in Pulaski, but as previously stated, since various subwatershed basins extend beyond the county boundaries, additional data was also needed. The United States Department of Agriculture (USDA) provides county-wide soil data in GIS form through their website[4]. All counties that surround Pulaski were downloaded and loaded into ArcMap for individual basin analysis and the soil types and their percentages within the basin are listed in the table provided. A description of the soil types shown can be found online at the USDA’s website, <http://soildatamart.nrcs.usda.gov/>. However, some basins have incomplete

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[3] Virginia Department of Forestry. *GIS Data Layers*. http://www.dof.virginia.gov/gis/datadownload.shtml.

[4] United States Department of Agriculture. *Natural Resources Conservation Service Soil Data Mart.* http://soildatamart.nrcs.usda.gov/.

soil statistics, so these basins will have percentages that do not add up to anything close to 100. The basins with incomplete soil data are listed below:

	Basins with Incomplete Soil Statistics	
PFAF ID:		*PFAF ID:*
1489234620000		1489234890000
1489234630000		1489234910000
1489234661000		1489234920000
1489234670000		1489234930000
1489234680000		1489234990000
1489234690000		1490292300000
1489234790000		1490292400000
1489234810000		1490292900000
1489234820000		1490293100000

Table 1. List of basins with incomplete soil statistics.

Google Earth

In addition to having access to an operational handbook, users can now access all information in Google Earth. Data from ArcMap was exported as a .kml file extension for easy import into Google Earth. All survey points and their symbology are exactly the same as in this handbook, but access to the information is much quicker and easier than thumbing through a binder of maps and materials. This will hopefully aid the operational forecaster at the WFO in Blacksburg whenever there is a quick need to determine flood stages for multiple locations in Pulaski County.

A simple extension for ArcGIS called *Export to KML* was downloaded from the internet and installed to run within ArcMap. This add-on took the existing ArcMap shapefile of the surveyed points, along with each point's symbology, and exported it as a .kml file. By using basic HTML coding, information about any surveyed point can be accessed by clicking on the point in question, which then opens a small pop-up box with all the collected information (Figure 6).

Figure 6. Google Earth overlaid with surveyed points and accessible information. Not shown in picture: Average Daily Traffic Count information which is readable in actual kml file.

Also very helpful and unique are two provided links, one to the upstream picture and one to the downstream picture. By clicking on either link, the corresponding upstream or downstream image for that exact location is loaded in a web browser window. This can allow anyone to see the surrounding environment upstream or downstream from a particular survey point. Only a few survey locations are without pictures, but there are over 630 digital images available that have been provided by this project.

To view the data in Google Earth, simply drag the *Measured_Points_with_Roadstats.kml* file (found on the included DVD) over to an open and running version of Google Earth and drop it in the main map window. This will then load all surveyed points, color-coded and ready for easy viewing. An additional file, *Measured_Points_with_Roadstats_GoogleMapsVersion.kml* has also been included, but is less efficient and slower to load; however, it does have uses associated with Google Maps.

RESULTS AND CONCLUSIONS

Discussion

With regards to the Flash Flood Risk Analysis Project completed in Missouri, there are significant improvements and adjustments. First, this project focuses on one individual county within the CWA for research purposes; the FFRAP surveyed the entire Springfield WFO coverage area. Covering individual counties of interest would allow for very accurate and local surveys, but does take considerable more time and effort. Second, the FFRAP did not evaluate the flood stage for streams along roadways in the Springfield CWA. This research project made surveying and calculating the flood stage(s) of individual streams the number one priority. And lastly, digital photographs were taken of all surveyed points which will allow for a better understanding of the actual surroundings, even if the forecaster has never been to the site.

This project has been a complete success and hopefully this additional data about local streams and their flood stage(s) will provide forecasters with information that can be used to help them when deciding to issue flash flood warnings over Pulaski County in the future.

Recommendations for Future Research

Although this project was completed within two months, it would be very difficult and time consuming to implement it across an entire CWA, if the project was performed as is. However, if certain counties or areas are deemed prone to flash flooding, then there should be no problem performing this research on additional counties. If a larger-scale approach is needed, the author recommends that only named roads and streams be used to determine survey points. By using only named streams, there is a significant reduction in the number of points required to be surveyed. This does survey many of the likely flash flood prone areas along known streams and tributaries, but it also lacks a complete picture of the smaller, unnamed streams (which are probably just as likely to see flash flooding as any named stream). Additionally, for areas of concern, any volunteers or residents from that vicinity that are willing to conduct field work should be given higher priority, since they are already familiar with the local area.

Concerning the operational use this research, for example, those surveyed points that are along main-stem streams and near the mouth of their associated basin could be exported from ArcGIS and imported into AWIPS. This could also be narrowed down further to include the above mentioned points but only those with the highest risk for flash flooding (<5’ stream rise).

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ACRONYMS, ABREVIATIONS AND TERMINOLOGY

AWIPS	Advanced Weather Interactive Processing System
CWA	County Warning Area
DEM	Digital Elevation Model
FFRAP	Flash Flood Risk Analysis Project
FS	Flood Stage, referring to the required height water would have to rise in a stream or creek to cause flooding of the nearby roadway
GPS	Global Positioning System
IT	Information Technology
NWS	National Weather Service
USDA	United States Department of Agriculture
VDOF	Virginia Department of Forestry
VDOT	Virginia Department of Transportation
WFO	Weather Forecast Office

Survey Location Types (page 10):

AS	Alongside Stream
B	Bridge
C	Culvert
LWC	Low Water Crossing