Flood Prone Roadway Study

2007

Prepared by:

Roanoke Valley Alleghany Regional Commission

This report was prepared by the staff of the Roanoke Valley-Alleghany Regional Commission in cooperation with the U.S. Department of Transportation (USDOT), the Federal Highway Administration (FHWA), and the Virginia Department of Transportation (VDOT). The contents of this report reflect the view of the author who is responsible for the facts and the accuracy of the data presented herein. The contents do not necessarily reflect the official views or the policy of the Federal Highway Administration, nor the Virginia Department of Transportation. This report does not constitute a standard, specification or regulation. Federal Highway Administration and Virginia Department of Transportation acceptance of this report as fulfillment of this planning study does not constitute endorsement/approval of the need for any recommended improvements, nor does it constitute approval of their location and design, nor commitment to fund any such improvements. Additional project level environmental assessments and/or studies of alternatives may be necessary.

The *Flood Prone Roadway Study* is available at:

http://rvarc.org/work/floodstudy.pdf

The *Flood Prone Roadway Study* regional map is available at:

http://rvarc.org/work/floodmap.pdf

Inquiries should be directed to: http://rvarc.org/work/floodstudy.pdf

Roanoke Valley-Alleghany Regional Commission
P.O. Box 2569
Roanoke, Virginia 24010
Phone: 540.343.4417
Fax: 540.343.4416
Email: rvarc@rvarc.org
Web site: www.rvarc.org

Acronyms

AFWS - Automated Flood Warning System
CDC - Centers for Disease Control
EPA – Environmental Protection Agency
FEMA – Federal Emergency Management Agency
FHWA – Federal Highway Administration
GIS – Geographic Information System
IFLOWS - Integrated Flood Observing and Warning System
LID – Low Impact Development
NOAA – National Oceanic and Atmospheric Administration
NPDES - National Pollution Discharge Elimination System
NWS – National Weather Service
RVAMPO - Roanoke Valley Area Metropolitan Planning Organization
TADD – Turn Around Don't Drown
VDEM - Virginia Department of Emergency Management
VDEQ - Virginia Department of Environmental Quality
VDOT - Virginia Department of Transportation
VPDES - Virginia Pollution Discharge Elimination System

INTRODUCTION

According to the National Oceanic and Atmospheric Administration, flooding causes more damage in the United States than any other severe weather related event, averaging $4.6 billion a year between 1984-2003 (NOAA 2006). Moreover, in 2004, the National Weather Service's Office of Climate, Water, and Weather Services, recorded that flooding in Virginia caused eleven deaths, second only to Texas. Additional Flooding Facts from the National Weather Service (2006) include:

- Nine out of ten "Presidential Disaster Declarations" result from natural phenomena in which flooding is involved.
- Eighty percent of flood deaths occur when people drive into water or simply walk into moving water.
- It only takes two feet of water to make a large vehicle buoyant enough to loose traction and float away. The smaller the vehicle the less water depth it takes to make it buoyant.

Source: National Weather Service: http://www.srh.weather.gov/floods/#types

The Centers for Disease Control (CDC) reports that over half of all flood-related drowning deaths occur when a vehicle is driven into hazardous flood water (National Weather Service 2006). This number is consistent with statistics for Virginia. Of the eleven flood-related deaths in Virginia in 2004, six victims, or 55 percent, were in vehicles. Many of these deaths occur in automobiles swept downstream while attempting to drive across flooded roadways. Often motorists will drive around barriers (e.g., signs, barricades) warning the road is flooded. These data help illustrate the relationship between flooding and the roadway network. Fortunately, these data also indicate that many of these deaths are preventable by simply avoiding areas already flooded and not attempting to travel across flooded streams or roadways.

Study Overview

This plan is an update and expansion of the *Rural Flood Prone Roadway Study* developed by the Fifth Planning District Commission in 1999. The *Rural Flood Prone Roadway Study* covered the portions of the region outside of the Roanoke Valley Area Metropolitan Planning Organization (RVAMPO) study area. The 2007 *Flood Prone Roadway Study* includes the entire Roanoke Valley-Alleghany Regional Commission's service area (Figure 1).

The purpose of this study is to identify, compile, and map flood prone roadways in the region and to provide information on how to mitigate the loss of life and property, especially as associated with flooded roadways in the region. In this study, a ***flood prone roadway*** is defined as any public road that has a history of being covered by enough water to render road surface, markings, and edges not visible to motor vehicle operators, bicyclists, and pedestrians. The flood prone roadways listed in this study include those identified as having a history of being flooded based on information from the Virginia Department of Transportation (VDOT), National Weather Service (NWS), and/or local sources (e.g., local government staff, elected officials).

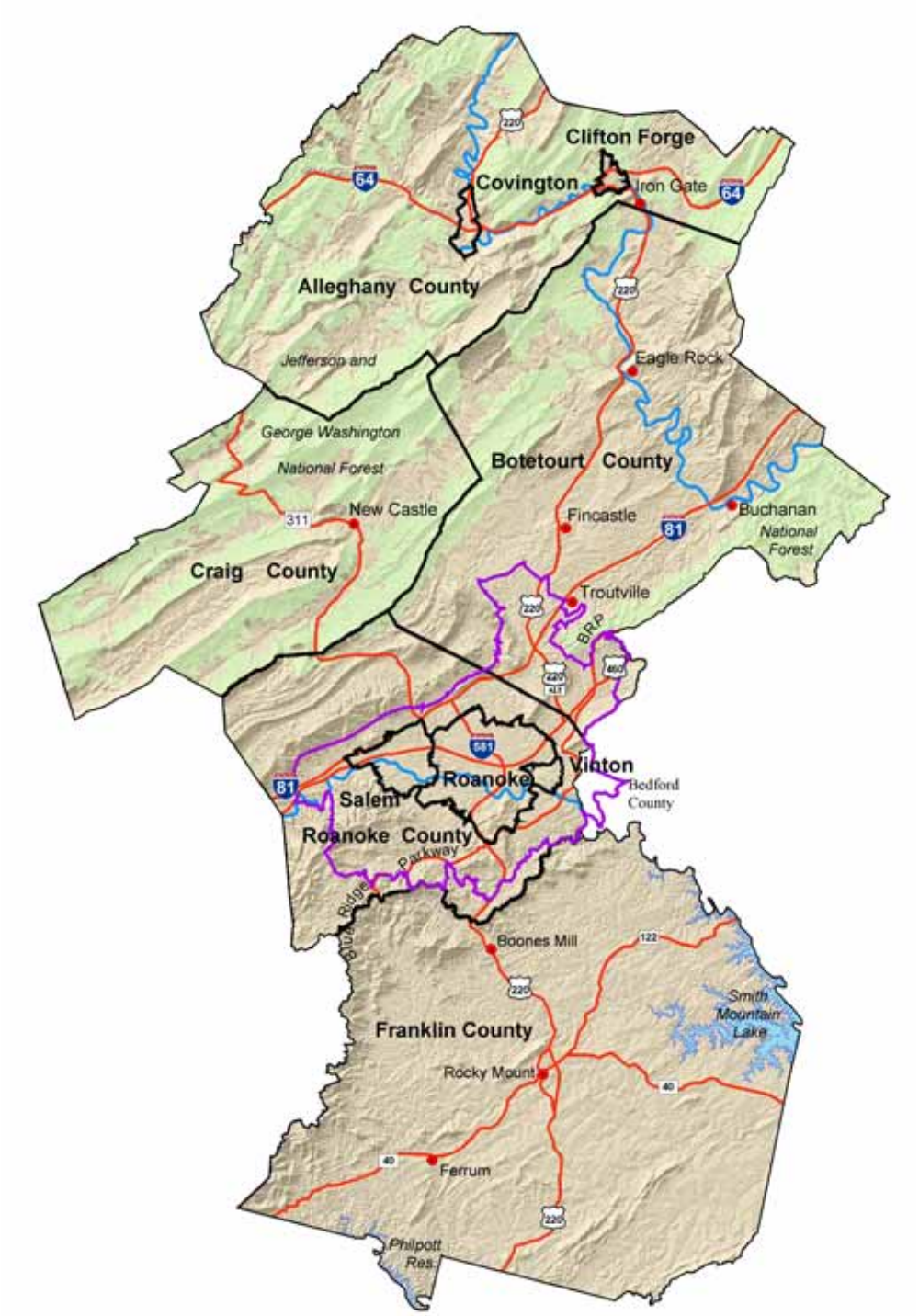


Figure 1. Flood Prone Roadway Study Area

As noted, many flood related deaths are preventable by simply avoiding areas already flooded and not attempting to travel across flooded streams or roadways. As such, from a transportation planning perspective, identifying and mapping flood prone roadways, are practical, initial steps in eliminating preventable deaths associated with flooded roadways.

In addition to flood prone roadways, this report also provides information on *flood prone areas* and *past flooding events*, compiled by the National Weather Service, Blacksburg office (Appendix A). Flood prone areas are those areas identified as having a history or potential to flood, while past flood events are rainfall events that created flash flood or flood conditions. (Note: these definitions are provided for informational purposes only and may or may not directly impact public roads).

This study also provides information on flood mitigation and flood hazard mitigation techniques and projects designed to reduce the frequency, duration, and magnitude of flooding as well as the potential hazards and loss of life or property. Also provided is an overview of NOAA and the NWS flood related programs and services.

Project Mapping

A regional map showing all identified flood prone roadways in the study area is provided in the back cover of this document and is available online at http://rvarc.org/work/floodmap.pdf. Additional data displayed on the map include streams and rivers, floodplains, fire and rescue stations, population centers, and public lands. While this study does not specifically list potential alternate routes to bypass flooded roadways, the associated mapping shows the entire roadway network and may assist in developing alternate routes or detours to avoid flooded roadways.

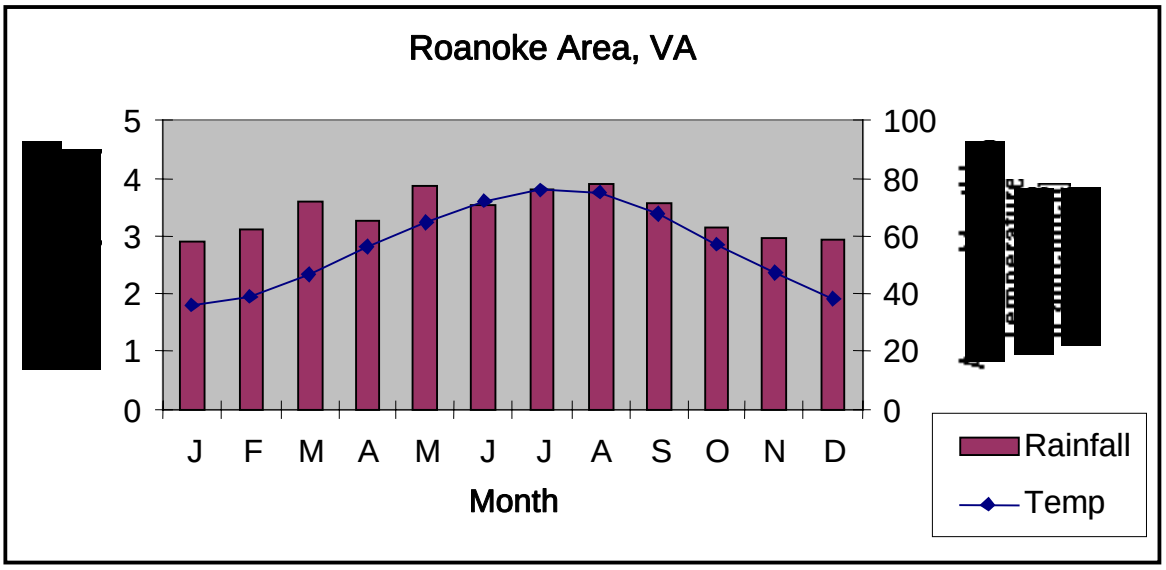
CLIMATE, TOPOGRAPHY, LAND USE, AND FLOODING

The climate and associated weather patterns, as well as the topography of an area can significantly influence the type, location, frequency, and magnitude of flooding events. In addition, topography influences such factors as settlement patterns, transportation infrastructure, and population distribution.

Climate

Given the geographic location of the region, the climate is generally classified as humid subtropical (Cfa). This climate type generally occurs in East coast locations between 20^{o} and 40^{o} North and South latitudes, which includes Virginia and much of the Southeastern United States. However, the presence of mountains, valleys, and rivers can create microclimates with considerable weather variations. As illustrated in Figure 2, the humid subtropical climate type is generally typified by ample precipitation distributed evenly throughout the year. As such, there is year-round potential for flooding in the region. A review of past flooding events provided in Appendix A shows that flooding in the region has occurred in nearly every month and season. Rainfall events that can lead to flooding in the area may be caused by thunderstorms or heavy rains from tropical cyclones (e.g., hurricanes, tropical storms or tropical depressions).

Figure 2
Climograph for Roanoke, Virginia



Source: Author, using data from the Southeast Regional Climate Center, Historical Climate Summaries for Virginia.
Period of Record: 8/ 1/1948 to 12/31/2005
Location: ROANOKE WSO AIRPORT, VIRGINIA (447285)

Topography and Land Use

While the topography varies considerably across the region, there are many features and landforms that are conducive to flooding events. Mountains, with steep slopes and fast flowing streams and runoff, dominate much of the region's topography. The topography also influences settlement patterns and the transportation infrastructure. As noted, much of the region is mountainous with population centers located in mountain and river/stream valleys that are susceptible to various types of flooding. In the Roanoke Valley, the cities of Roanoke and Salem, and the Town of Vinton are located adjacent to the Roanoke River. In the Alleghany Highlands, the City of Covington and the towns of Clifton Forge and Iron Gate are also located in close proximity to the Jackson River. Moreover, the towns of Buchanan and Eagle Rock are located on the James River. These rivers and their tributaries are subject to periodic flooding and pose a significant flood risk to the localities.

Types of Flooding

Flooding type can be classified based on characteristics such as location and duration. This study considers the three types of flooding that are likely to afflict the area: urban flooding, flash flooding, and river flooding.

♦ Urban Flooding

Urban flooding occurs when the amount of runoff (i.e., stormwater) exceeds the amount that can be absorbed into the ground or carried away by the existing drainage systems, resulting in localized flooding. Urban flooding can occur very rapidly following or during periods of heavy rainfall. Within a few minutes or hours, streets and low-lying areas can be flooded (Figure 3). Urban flooding can also allow storm water to flow into the sanitary sewer system, often overwhelming the sewage treatment plant's capacity.

Increases in the frequency and magnitude of urban flooding are often directly related to the amount of impervious surfaces: parking lots, rooftops, roads, and so forth. In general, as impervious surface increases, the amount of runoff also increases. Furthermore, urban flooding can be caused or exacerbated when storm drains or ditches become blocked with leaves or other debris (Figure 4).

♦ Flash Flooding

Flash flooding is characterized by the rapid accumulation of runoff or surface water from any source. This type of flooding can impact small creeks and streams by causing them to overflow their banks and, oftentimes, flood roadway and other structures adjacent to the stream. Flash floods are rapidly occurring events that can begin within a few hours of heavy rainfall, and are responsible for the greatest number of flood-related deaths. Of the eleven flood-related deaths in Virginia in 2004, all were attributable to flash flooding (NWS 2004). Flash flood-producing rains can also trigger mudslides and other types of mass wasting that can block roadways.

- **River Flooding**

River flooding occurs when the actual amount of river flow (discharge) is greater than the capacity of the river channel, resulting in the river overflowing its banks and flooding the areas alongside the river (i.e., floodplain). River floods tend to be longer in duration than flash or urban floods. The James River and the Roanoke River are the major rivers in the area and are subject to periodic flooding. The Roanoke River and several tributaries have experienced several severe floods in recent years (2004, 2003, 1995, 1992, 1989, 1987, 1985, 1979) resulting in flooding and requiring evacuation of homes and businesses in low-lying areas (City of Roanoke 2006). In November 1985, the flooding of the Roanoke River and many tributaries remains the worst flooding on record. Other rivers in the area include the Black Water River and Pigg River in Franklin County, and the Jackson River and Cow Pasture River in Alleghany. There are also numerous smaller tributary streams in the area.

Figure 3. *Street Closed sign blocking access to a flooded street in the City of Roanoke.*

Figure 4. *Flooded roadway caused by leaves blocking the storm drainage ditch.*

FLOOD PRONE ROADWAYS

Flood prone roadways identified in the study area are included in the following tables. The roadways listed in this study include those identified as having a history of being flooded based on information from the Virginia Department of Transportation (VDOT), National Weather Service (NWS), and/or local sources (e.g., local government staff, elected officials). Maps numbers listed in these tables correspond to the flood prone roadway segments included on the regional flood prone roadways map located in the back cover of this document.

Table 1
Flood Prone Roadways
Alleghany County

Map Number	Road Name	Route Number	Flooding Location Description
A1	Douthat Road	629	Just before the Buckhorn Store
A2	Indian Draft Road	600	I-64 bridge
A3	Indian Draft Road	600	Humpback Bridge
A4	Rich Patch Road	616	Just below Rich Patch Union Church near the intersection of Routes 616 and 621(Roaring Run Road)
A5	White Gap Road	623	About 2 miles from Route 616 at the creek intersection just beyond Bryant Farm
A6		634	Along the Cowpasture River below Sharon School

Table 2
Flood Prone Roadways
Botetourt County

Map Number	Road Name	Route Number	Flooding Location Description
B1	Ball Park Road	685	Opposite side of Craig Creek
B2	Barger Drive	819	Confluence of Little Patterson Creek & Patterson Creek
B3	Breckinridge Mill Road	600	Two miles west of Fincastle
B4	Nace Road	640	Spec, Lithia, and Pico areas
B5	Country Club Road	665	Intersection of SR 600 Haymakertown
B6	Craig Creek Road	615	Several spots from the James River to Roaring Run
B7	Craig Creek Road	615	Just west of Oriskany near Silent Dell, and at Roaring Run
B8	Ellis Run Lane	644	Spec, Lithia, and Pico areas
B9	Fringer Trail	645	Spec, Lithia, and Pico areas
B10	Goode Lane	643	Spec, Lithia, and Pico areas
B27	Greyledge Road	611	Several spots where Purgatory Creek crosses
B11	Haymakertown Road	600	Intersection of 665 near Haymakertown
B12	Jennings Creek Road	614	From Arcadia to the dead end
B13	Lake Catherine Drive	649	Four miles northwest of Buchanan
B14	Lapsley Run Road	726	James River to the intersection with SR 687
B15	Lee Highway	US 11	Near intersection with Hardbarger Road (Route 636)
B16	Middle Creek Road	618	Middle Creek
B17	Middle Creek Road	620	Middle Creek
B18	Mt. Joy Road	625	Near intersection with Park Vista Drive
B19	Patterson Trail	683	To US 220
B20	Plank Road	610	Near I-81 in the extreme northeast portion of the county
B21	Poor Farm Road	681	Between SR 679 and 630 just northeast of Fincastle
B22	Pulaski Mine Road	689	Spec, Lithia, and Pico areas
B23	Springwood Road	630	Between Timber Ridge Road (635) and Thrasher Road (625)
B24	Sugar Tree Hollow	684	Area adjacent to Little Patterson Creek
B25	Tinker Mill Road	674	Daleville area 0.5 miles west of US 220
B26	Willowbrook Lane	US 460	Glade Creek near Willow Brook Mobile Home Park

Table 3
Flood Prone Roadways
Town of Clifton Forge

Map Number	Route Name	Flooding Location Description
CF1	Commercial Street	Upper end in an area referred to as "Neddleton Addition"
CF2	Rose Street	Small bridge above the 900 Block
CF3	Rose Street	Parking lot bordering Dry Creek
CF4	West Main Street	Downtown area

Table 4
Flood Prone Roadways
City of Covington

Map Number	Route Name	Flooding Location Description
C2	Court Street	Downtown area
C3	Dalton Avenue	Sunnydale area
C4	Dry Run Road	North Alleghany Drive to Hillcrest Drive
C5	Gilliam Street	Rayon View area
C6	Gordon Street	Parrish Court Avenue
C7	Gum Avenue	Rayon View area
C8	Lyman Avenue	Sunnydale area
C9	Maple Avenue	Downtown area
C10	Marshall Street	Idlewilde area
C11	Michigan Avenue	Idlewilde area
C12	North Alleghany Drive	Dry Run to Hillcrest Drive
C13	North Craig Avenue	Downtown area
C14	North Lexington Avenue	Downtown area
C15	Parrish Court Avenue	Parrish Street, Phillip Street, Gordon Street
C16	Parrish Street	Parrish Court Avenue
C17	Phillip Street	Parrish Court Avenue
C18	Plum Street	Rayon View area
C19	Riverside Avenue	Downtown area
C20	Royal Avenue	Downtown area
C21	South Carpenter Drive	Idlewilde area
C22	SR 18	Bridge over Jackson River
C23	Trout Street	Idlewilde area
C24	West Chestnut Street	Downtown area
C25	West Jackson Street	Lower end
C26	Wood Street	Rayon View area

Table 5
Flood Prone Roadways
Craig County

Map Number	Route Name	Flooding Location Description
CC1	311	Broad Run bridge - confluence of Craig Creek and Broad Run approximately three miles south of New Castle
CC2	611	Portions along Craig Creek
CC3	612	Craig Creek
CC4	614	Low water bridge
CC5	614	Intersection of Route 681
CC6	618	From about 0.75 miles north of Route 311to four miles north.
CC7	623	About 4 miles southwest of New Castle
CC8	627	One mile southeast of the town of Simmonsville at a low water bridge
CC9	647	Near the end of state maintenance
CC10	651	About five miles southwest of Abbott
CC11	681	Intersection of Route 614

Table 6
Flood Prone Roadways
Franklin County

Map Number	Route Name	Route Number	Flooding Location Description
F1	Ashpone Tavern Road	707	Intersection with Route 674 (Doe Run Road)
F2	Bar Ridge Road	659	Intersection with Route 926 (Tobacco Road) about 0.78 miles north of Route 890 at low water bridge
F3	Blue Bend Road	709	0.4 miles south of Route 812 (Jamestown Road)
F4	Briar Mountain Road	929	0.8 miles west of Route 756 (Fishburn Mountain Road)
F5	Callaway Road	641	0.3 miles south of Route 740 (Algoma Road)
F6	Coles Creek Road	643	1.5 miles south of Route 737 (Deyerle Knob Road)
F7	Doe Run Road	674	Intersection with Route 707 (Ashpone Tavern Road)
F8	Doe Run Road	674	Intersection with Route 707 about 0.56 miles west of Route 954
F9	Dovetail Road	950	0.8 miles north Route 666 (Merriman Way Road)
F10	Ferrum Mountain Road	602	0.5 miles south of Route 641(Callaway Road)
F11	Franklin Street	40	0.2 mile east of Route 602 (Ferrum Mountain Road)
F12	Hardy Road	636	0.5 miles north of Route 677 (Middle Valley Road)
F13	Hurds Branch Road	818	0.5 miles west of Route 793 (Runnett Bag Road)
F14	Inglewood Drive	672	0.75 miles north of Route 670 (Burnt Chimney Road)
F15	Madcap Road	736	2.5 miles north of Route 756 (Old Forge Road)
F16	Madcap Road	736	3.0 miles north of Route 756 (Old Forge Road)
F17	Mary Bett Hollow Road	807	Various places east of Route 793 (Runnett Bag Road)
F18	Pembrook Road	690	0.05 mile east of Route 767 (Prillaman Switch Road)
F19	Rambling Rose Road	781	0.1 miles south of Route 40 (Franklin Road)
F20	Red Valley Road	657	0.6 miles south of Route 684 (Boone Mill Road)
F21	Rufus Road	759	0.6 miles east of Route 608 (Fork Mountain Road)
F22	Ruritan Road	756	0.6 miles east of Route 754 (Falcon Ridge Road)
F23	Sutton Hollow Road	717	0.5 miles north of Route 890 (Snow Creek Road)
F24	Turkey Branch Road	836	0.5 miles north of Route 793 (Runnett Bag Road)
F25	Wades Gap Road	726	1.0 miles west of Route 613 (Naff Road)
F26	Wades Gap Road	727	1.5 miles east of Route 613 (Naff Road)
F27	Wright Road	970	0.23 mile east of Route 613 (Naff Road)

Table 7
Flood Prone Roadways
City of Roanoke

Map Number	Route Name	Flooding Location Description
R1	10th Street	Intersection of Shadelawn Avenue
R2	13th Street	Intersection with Eastern Avenue and Tinker Creek
R3	Arbor Avenue	Riverview Area
R4	Arbutus Avenue	Riverview Area
R5	Baldwin Avenue	Intersection with Tuck Street
R6	Bennington Street	Jamestown Area
R7	Boulevard Street	Intersection with Salem Ave. (Shaffers Crossing)
R8	Brambleton Avenue	Crossing of Murray Run Creek
R9	Campbell Avenue	Near intersection of 10th Street
R10	Cravens Creek Road	Intersection with Deyerle Road
R11	Deyerle Road	Intersection with Valentine Road
R12	Edgewood Street	Near intersection with Brandon Road
R13	Franklin Road	Intersection with Brandon Road
R14	Franklin Road	Intersection with Broadway Avenue
R15	Jefferson Street	Intersection with Reserve Avenue
R16	King Street	Intersection of Berkeley Avenue and Richards Avenue
R17	Piedmont Street	Intersection with Hamilton Terrace
R18	Wiley Drive	Various spots
R19	Wise Avenue	Crossing of Tinker Creek

Table 8
Flood Prone Roadways
City of Salem

Map Number	Route Name	Flooding Location Description
S1	Apperson Drive	Between Orchard Drive and Riverside
S2	Colorado Street	Between Rowan Street and Riverside Drive
S3	East Main Street	Intersection with Kessler Mill
S4	East Riverside Drive	Between Apperson and McVitty
S5	Electric Road	Near intersection with Apperson Drive
S6	Epperly Lane	Kessler Mill Road to Terminus
S7	Front Street	Between Riverside Drive and Riverside Drive
S8	Horner Lane	Near Wildwood Road
S9	Lancing Drive	Salem Ridge Apartments, aka Willow River
S10	Mill Lane	Between West Main Street and Riverside Drive
S11	Pine Bluff	Kessler Mill Road to Sycamore
S12	River Side Drive	Apperson Drive to Colorado Street
S13	Sycamore Drive	Pine Bluff to Terminus
S14	Union Street	Between Fourth Street and Eddy Street
S15	West Main Street	Intersection with Wildwood Road
S16	West Main Street	Between Poplar Street and Turner Street
S17	Wildwood Road	Intersection with West Main Street

Table 9
Flood Prone Roadways
Roanoke County

Map Number	Route Name	Route Number	Flooding Location Description
RC1	Back Creek Road	676	Between US 220 and 615
RC2	Bandy Road	666	Middle Back Creek Bridge
RC3	Bandy Road	666	5000 Bandy Road
RC4	Barley Drive	646	Various spots near River
RC5	Bendermere Road	699	Masons Creek Bridge
RC6	Bent Mountain Road	US 221	Intersection of Twelve O'clock Knob Road (694)
RC7	Bottom Creek Lane	637	Various spots
RC8	Bottom Creek Road	607	1.5 miles west of intersection with Route 711
RC9	Bottom Creek Road	607	724 Bottom Creek Road
RC10	Bradshaw Road	622	Various spots near Creek
RC11	Carson Road	758	Near intersection with Lake Back O Beyond Dr.
RC12	Cartwright Road	1726	Near Crystal Creek
RC13	Carvins Cove Road	740	Bennet Springs to Carvins Cove
RC14	Carvins Cove Road	740	Above Carvins Cove reservoir near Bennett Springs
RC15	Clearwater Avenue	1861	Various spots near Creek
RC16	Coleman Road	735	Various points
RC17	Cotton Hill Road	688	West of Intersection with Route 613
RC18	Crawford Road	1736	400 block
RC19	Creekwood Drive	1124	Near intersection with Beaverbrook
RC20	Cresthill Drive	1658	Garst Mill Bridge
RC21	Dent Road	623	From Williamson Road to Brookside
RC22	Dutch Oven Road	863	Various spots near Creek
RC23	Electric Road	419	Near intersection with Cordell Drive
RC24	Electric Road	419	Intersection with McVitty Road
RC25	Ferguson Valley Road	721	Various spots along Creek
RC26	Five Oaks Road	6512	Intersection with Bent Mountain Road
RC27	Florist Road	623	Near intersection with Verndale Drive
RC28	Garst Mill Road	682	Near Intersection with Halevan Road
RC29	Glade Creek Road	636	Near intersection with Bonsack Road
RC30	Grandin Road Extension	686	West of Meadow Creek Drive (1390)
RC31	Green Ridge Road	628	3000 Block of Green Ridge Road
RC32	Halevan Road	1361	At Garst Mill Park Road
RC33	Harwick Drive	769	Various spots
RC34	Hershberger Road	101	East of intersection with Plantation Road

Table 9 (Continued)
Flood Prone Roadways
Roanoke County

Map Number	Route Name	Route Number	Flooding Location Description
RC35	Indian Head / Bohon Hollow Rd.	734	Various spots
RC36	John Richardson Road	743	Near intersection of Hershberger Dr. and Plantation Road
RC37	Keagy Road	685	4400 Keagy Road
RC38	Kessler Mill Road	630	Various spots
RC39	Lakemont Drive	1446	Various locations
RC40	LaMarre Drive	1815	Various spots near Creek
RC41	Little Bear Road	680	Various spots
RC42	Loch Haven Road	1894	2 miles east of Route 419
RC43	McVitty Road	1662	Intersection with Castle Rock Road
RC44	McVitty Road	1662	3100 McVitty Road
RC45	Merriman Road	613	Near Penn Forest Elementary
RC46	Ogden Road	681	At Pebble Creek
RC47	Old Mountain Road	864	Various spots near Creek
RC48	Palm Valley Road	1897	Sun Valley Subdivision
RC50	Plymouth Street	836	Near Brookside
RC51	Ran Lyn Drive	745	Near Intersection with South Roselawn
RC52	River Road		Various places near river
RC53	Rocky Road	744	635 Rocky Road
RC54	Shadwell Road	601	Near intersections with Ashton Rd. and Summerview
RC56	South Campus Drive	6081	Various spots near Creek
RC57	Starkey Road	904	At Back Creek Tributary B
RC58	Starlight Lane	615	Between Boones Chapel Rd. and Blue Ridge Parkway
RC59	Sugarloaf Mountain Road	692	Near Mud Lick Creek
RC61	Texas Hollow Road	641	Various spots
RC62	Tinsley Lane	711	Near intersection with Bottom Creek Road
RC63	Tree Top Camp Road	871	Various spots
RC64	Twelve O'clock Knob Road	694	Various locations
RC65	Verndale Drive	1867	Sun Valley Subdivision
RC66	West River Road	639	Various places
RC68	West Riverside Drive	639	Various spots near River
RC70	Willow Branch Road	677	Various spots near Creek
RC71	Wood Haven Road	628	Near intersection with Willow Creek Drive
RC72	Yellow Mountain Road	668	Near intersection with US 220

Table 10
Flood Prone Roadways
Town of Vinton

Map Number	Route Name	Flooding Location Description
V1	Hardy Road	Town of Vinton / Roanoke County CL
V2	Virginia Avenue	Town of Vinton / City of Roanoke CL
V3	Walnut Avenue	From 4th Street to 8th Street

FLOOD MITIGATION

Many localities in the area are working on a range of flood mitigation projects designed to reduce the frequency, duration, and magnitude of flooding and associated hazards. These projects include both structural and non-structural mitigation techniques. This section provides examples of various flood mitigation techniques and efforts in the study area. However, examples are provided for discussion purposes and are not intended to be a comprehensive accounting of all flood mitigation efforts.

♦ Roanoke River Flood Control Project

In 1989, voters in the City of Roanoke passed a $7.5 million bond referendum for the Roanoke River Flood Reduction Project. This is a joint project with the U.S. Army Corps of Engineers and includes Roanoke River channel improvement and flood proofing of public facilities. When complete, this project may reduce the flooding of roadways in the City of Roanoke.

♦ Street Cleaning and Leaf Collection

Often flash and urban flooding is caused or worsened when storm drains become blocked with debris during heavy rainfall events. It is therefore important to regularly clean storm drains and ditches to ensure maximum operational efficiency of the drainage systems to help mitigate flash and urban flooding in the region, especially in more urban areas.

Figure 5. *Street cleaning in the City of Roanoke.*

The City of Roanoke's Transportation Division regularly sweeps streets in the city to remove debris that could potentially block storm drains (Figure 5). The City of Roanoke also conducts a seasonal city-wide collection of leaves during a six-week period in the fall. The City of Roanoke's leaf collection program is a combined effort of the city's Department of Public Works (Divisions of Transportation and Solid Waste Management), the Roanoke City Sheriff's Office, and the Roanoke City Department of Parks and Recreation (Roanoke 2006). Additional information on the City of Roanoke's Leaf Collection Program is available by accessing http://www.roanokeva.gov/WebMgmt/ywbase61b.nsf/CurrentBaseLink/N255ZRNJ153JEASEN.

♦ Stormwater Management

Several communities in the area, including Botetourt and Roanoke Counties and the Cities of Roanoke and Salem, have applied for a Virginia Pollution Discharge Elimination System (VPDES) permit from the Virginia Department of Environmental Quality. The US EPA under the National Pollution Discharge Elimination System

(NPDES) Phase II regulations mandated this permit. These permits, renewed every five years, outline proactive steps localities will be taking to improve stormwater quality. While the focus of this program is stormwater quality, it also impacts water quantity and associated flooding risks. For example, increased impervious surfaces from development not only negatively impacts stormwater *quality*, it also increases the *quantity* or amount of stormwater runoff, thereby increasing the risk of urban flooding. Activities such as street sweeping and storm drain maintenance improve stormwater quality while reducing stormwater quantity and associated flooding risks.

- **Urban Forestry**

Trees provide a range of aesthetic, economic, recreational and environmental benefits. Increased tree cover provides stormwater management benefits such as slowing and reducing runoff from storms and stabilizing the soil, thereby possibly reducing the occurrence and severity (i.e., peak flow) of stormwater runoff, and potential flooding of area roadways. For example, the Roanoke City Council adopted the Urban Forestry Plan as an element of Vision 2001-2020, the City's comprehensive plan. This plan calls for increasing the tree canopy in the City of Roanoke to 40 percent of the land cover, from the 32 percent of land currently covered by trees (Urban Forestry Plan 2003).

- **Low Impact Development**

One way to address stormwater runoff is through Low Impact Development (LID). The Natural Resources Defense Council states that LID is the application of cost-effective, lot-level stormwater management strategies that integrate green space, native landscaping, natural hydrologic functions, and various other techniques to generate less runoff from developed land. LID seeks to replicate predevelopment hydrology and reduce the impacts of development, as illustrated through Figure 6. Additional information on LID is available at http://www.nrdc.org/water/pollution/storm/chap12.asp.

Figure 6. *Parking lot in Wasena Park constructed to allow water to infiltrate instead of producing runoff.*

- **Open Space and Greenways**

Open space and greenways are corridors of protected open space used for recreation, conservation, and transportation. Additional information and maps of the greenway in the Roanoke Valley are available at the Roanoke Valley Greenways web site http://www.greenways.org.

FLOOD HAZARD MITIGATION AND SAFETY

Flooding is likely to occur at some point, thereby necessitating the need to mitigate the loss of property and life associated with flooding events. NOAA and the NWS have developed a range of programs and resources to assist localities and citizens in flood hazard mitigation.

Flash Flood Terminology

To assist in emergency preparedness and mitigate the potential hazards associated with flooding, NOAA has developed the following flash flood terminology:

- **Flash Flood Watch** - Indicates that flash flooding is a possibility in or close to the watch area. Those in the affected area are urged to be ready to take action if a flash flood warning is issued or flooding is observed. These watches are issued for flooding that is expected to occur within 6 hours after the heavy rains have ended.

- **Flash Flood Warning** - A flood warning is issued for life/property threatening flooding that will occur within 6 hours. It could be issued for rural or urban areas as well as for areas along the major rivers. Very heavy rain in a short period of time can lead to flash flooding, depending on local terrain, ground cover, degree of urbanization, amount of man-made changes to the natural river banks, and initial ground or river conditions. Dam breaks or ice jams can also create flash flooding.

- **Flash Flood Statement** - A Flash Flood Statement is issued to inform the public about current flash flood conditions. These statements usually contain river stage information if major streams or rivers are involved.

- **Urban/Small Stream Flood Advisory** - Alerts the public to flooding, which is generally only an inconvenience (not life-threatening) to those living in the affected area. Issued when heavy rain will cause flooding of streets and low-lying places in urban areas. Also used if small rural or urban streams are expected to reach or exceed bankfull. Some damage to homes or roads may occur.

Source: http://www.noaa.gov/floods.html

StormReady

StormReady is a volunteer program, administered by the National Weather Service (NWS) to help communities better prepare for and mitigate effects of extreme weather-related events through better planning, education, and awareness. National StormReady guidelines set minimum requirements for the program. Once a community meets the requirements, it should send the application to the NWS. From there the application will go to your Local StormReady Advisory Board for review and to set up a site visit to verify the information in the application. Once the local board approves the application, the community can request StormReady signs (Figure 7). Additional information on StormReady is available at http://www.stormready.noaa.gov.

Figure 7. *StormReady Community sign. Source: National Weather Service.*

NOAA Weather Radio All Hazards (NWR)

NOAA Weather Radio All Hazards (NWR) is a nationwide network of radio stations broadcasting continuous weather information directly from a nearby National Weather Service office. NWR broadcasts National Weather Service warnings, watches, forecasts and other hazard information 24 hours a day (NWS, 2006). NOAA Weather Radio All Hazards transmitters broadcast on one of seven VHF frequencies from 162.400 MHz to 162.550 MHz. NWR requires a special radio receiver or scanner capable of picking up the signal (Note: broadcasts cannot be heard on a simple AM/FM radio receiver). County coverages and frequencies for the region are provided in Appendix B. Additional information on NWR is available at http://www.weather.gov/nwr.

Turn Around Don't Drown (TADD)

TADD is a NOAA National Weather Service campaign to warn people of the hazards of walking or driving a vehicle through floodwaters. The Federal Highway Administration (FHWA) has approved the *Flooding Ahead Don't Drown* sign (Figure 8) as an official Incident Road Sign. Additional information on TADD is available at http://www.weather.gov/os/water/tadd/.

Figure 8: *Turn Around Don't Drown Road Sign. Source: NOAA*

Advanced Hydrologic Prediction Service (AHPS)

The Advanced Hydrologic Prediction Service, operated by the National Weather Service, provides forecasts of river levels and river flow volumes from an hour to a season for areas large and small, including river forecast information such as:

- How high the river will rise
- When the river will reach its peak
- Where property will be flooded
- How long flooding will continue
- How long a drought will last

Additional information on AHPS is available at http://www.nws.noaa.gov/oh/ahps.

Federal Integrated Flood Observing and Warning System (IFLOWS)

IFLOWS uses communications technology and software to collect real time sensor data (rain and stream) from remote locations and disseminate the data among government organizations responsible for public safety. IFLOWS' purpose is to reduce the annual loss of life from flash floods, reduce property damage, and reduce disruption of commerce and human activities. The National Weather Service IFLOWS is a cooperative venture between the National Weather Service (NWS) and Appalachian states and was developed as part of the National Flash Flood Development Plan in 1978. For further details, visit the NOAA web site at http://www.nws.noaa.gov/om/hod/SHManual/SHMan025_IflowsFile.htm.

According to the Virginia Department of Emergency Management (VDEM), IFLOWS is installed in 38 jurisdictions in the western part of the state in the Blue Ridge Mountains. From Lee County in southwestern Virginia, it extends to Warren County in the northwestern area of the state. VDEM listed a total of 328 rain sensors and 60 stream sensors. Also in these 38 jurisdictions is an IFLOWS communications system that utilizes VHF radio/microwave communications technology to carry a voice network. This

network consists of the 38 localities, the Virginia Operations Center (VEOC), and the NWS offices in Virginia (VDEM). The IFLOWS software also monitors the data as it is received and issues audible warnings when thresholds are exceeded. The NWS issues the guidance that is the amount of rainfall to begin small stream flooding in 1-hour, 6-hour, 12-hour and 24-hours. Using these as upper values for warning levels the coordinator can set percentages for the levels of warning they desire.

Additional information on IFLOWS in Virginia is available at http://www.vaemergency.com/programs/iflows/index.cfm. IFLOWS data are also available on the Automated Flood Warning System (AFWS) web site at http://www.afws.net.

STUDY SUMMARY

Due to a range of factors - topography, weather and climate, settlement patterns, and other natural and cultural features - there is, and will continued to be, significant potential for flooding throughout the study area during heavy rainfall events. Often this flooding study area However, as noted throughout this documents, there are numerous techniques and efforts available to mitigate flooding and associated loss of life and property. This section provides a summary of the findings from this study.

1. The most effective way to loss of life related to flooded roadways is for motorists to simply avoid driving on roadways that are flooded. Flash flooding can develop in a very short time in heavy rainfall, making it impossible for emergency managers to block every roadway. As such, it is incumbent on motorists to understand the dangers of flooded roadways and avoid them. Education and increased awareness of the dangers of flooding and vehicle safety should be increased through existing safety programs, several of which are outlined in this document.

2. While a large number of roadway sections have been identified as being prone to flooding, the consistency, quality, and specificity of the data vary considerably across data sources. A structured reporting and inventory system would provide a framework for better documentation of problem areas. Such a system could provide a range of information for use by local officials and emergency personal during flooding events. A comprehensive reporting and inventory system could also assist in:

    - Identifying additional flood prone roadways
    - More accurate mapping
    - Alternate route selection
    - Evaluating possible solutions to mitigate the impact of flooded roadways in the future
    - Providing attributes for a given roadway segment subject to flooding to use in forecasting roadway flooding in problem areas

The roadways identified in this study and associated mapping, while not comprehensive, represent the most detailed accounting of flood prone roadways available in the region. To increase the utility of collected data, future data collection efforts should consider inclusion of additional information and attributes related to flood prone roadways identified. These data may include, but are not limited to:

- Route name and route number
- Specific flooding location description
- Geographic coordinated
- Low water bridges
- Stream name
- Type of flooding
- Alternate routes
- Frequency of flooding

- Typical flood duration
- Associated weather condition information

3. Future land use decisions and development and maintenance of the transportation infrastructure can greatly impact flooding on roadways in the study area. In addition to specific flood mitigation projects, local governments can utilize planning and land use documents, such as zoning regulations and subdivision ordnances, to mitigate flooding and damages associated with flooding when it invariably occurs. Moreover, new road and bridge construction should follow basic guidelines to reduce the impact of flooding. VDOT has developed a range of guidance documents related to roadway and bridge construction. Examples of VDOT guidance documents include:

   - 2002 Drainage Manual

   http://www.virginiadot.org/business/locdes/hydra-drainage-manual.asp

   - 2001 Road and Bridge Standards – Volume 1 and Volume 2

   http://virginiadot.org/business/locdes/Electronic_Disclaimer.asp

   - Road Design Manual – Volume 1

   http://www.extranet.vdot.state.va.us/locdes/Electronic%20Pubs/2005%20RDM/RoadDesignCoverVol.1.pdf

Further documentation of flood prone roadways and mitigating the associated impacts will require continued cooperation and input from a range of stakeholders including, but not limited to, VDOT, federal, state, and local emergency services personnel, local government staff and elected officials, and the National Weather Service. The Regional Commission, through work on a range of regional planning projects, has worked closely with these stakeholders and is available to continue to facilitate regional transportation safety and emergency management planning.

Appendix A

Past Flooding Events in the Region, by Locality

Alleghany County

Past Small Stream/Flash Flooding

5/20/01 - Radar estimated rainfall of 2.5 to 3.0 inches in about 2 hours in a small area around Douthat State Park in southern Bath County. Nearby Iflows indicated the radar was underestimating and that the rainfall was probably 3.0 to 3.5 inches. This rainfall caused flash flooding along Wilson Creek, washing out roads and damaging a store in the state park in Bath County, and flooding State Rte 629 in northern Alleghany County north of Cliftondale.

5/22/01 - Radar estimated 1.5 to 1.75 inches in most of the southeastern quarter of the county. Iflows indicates this is a good estimate- the Nichols knob gage had 1.22 inches in 30 minutes, and 1.42 in 45 minutes. This caused flash flooding along Blue Springs Run, and Wilson Creek, closing roads. The Cowpasture River and Potts Creek rose above flood stage at USGS gages. The Cowpasture River rose to 9.7 feet...flood stage is 8 feet. Potts Creek near Covington rose to 7.5 feet...flood stage is 7 feet.

8/10/01 - Radar estimated 1.5 to 2.0 inches of rain across the northern half of the city of Covington. A nearby IFLOWS gage showed 0.98 inches in 1 5 minutes, 1.57 in 30 minutes, and 1.89 in an hour. This caused considerable street flooding and closures in the city.

02/22/03 - During the period from late 2/21 through early 2/23, the CWA was affected by a heavy rain event. Rainfall through 22/12z ranged from 0.5 to 1.0 inches, with the heaviest along and west of the Blue Ridge. Most of the rest of the rainfall fell between 22/12z and 22/18z. Total storm rainfall for Alleghany County ranged from 2.0 to 2.5 inches, with the ending 6 hour amounts around 1.0 inch. This caused a small feeder stream to Dunlap Creek to flood Rte 600.

Source: National Weather Service, Blacksburg office

Botetourt County

Past Small Stream/Flash Flooding

08/01/00 – Slow moving thunderstorms brought an estimated 3 to 4 inches of rain in about 2 hours to an area from Oriskany, to Eagle Rock to Daggers Springs. VDOT had a report of 4.2 inches near Eagle Rock. This caused Craig's Creek to wash out part of State RT 817 near Oriskany. A small tributary of the James River near Eagle Rock washed out a culvert under State RT. 743, and Mill Creek to flood State Rte 612 near Daggers Springs.

08/02/00 - A slow moving thunderstorm brought a radar estimated 2.5 to 3.0 inches of rain in about a 2 hour time period to a small area just south of the town of Oriskany. This caused flash flooding along Little Patterson Creek in the national forest, making FR184 impassable.

09/03/00 - Radar estimated rainfall of 1.5 to 1.75 inches in an hour caused minor flooding along Craig Creek near Oriskany.

02/22/03 - During the period from late 2/21 through early 2/23, the CWA was affected by a heavy rain event. Rainfall through 22/12z ranged from 0.5 to 1.0 inches, with the heaviest along and west of the Blue Ridge. Most of the rest of the rainfall fell between 22/12z and 22/18z. Total storm rainfall for Botetourt County ranged from 2.0 to 3.0 inches, with the ending 6-hour amounts 1.5 to 2.0 inches, with the highest in the southwest. This caused Craigs Creek to flood route 615 near Roaring Run, with 4 feet of water over the road. It also flooded routes 615 and 683 near Eagle Rock. There was flooding along Back Creek in the Lithia area, flooding and causing damage to route 640. There was minor flooding along Tinker Creek in the Daleville and Cloverdale areas. Catawba Creek flooded route 600 near the intersections of 665 and 748 in Haymakertown.

09/19/03 - The remnants of tropical storm Isabel brought upslope heavy rain on the northwest side of the Blue Ridge near the Peaks of Otter in extreme eastern Botetourt County. Radar and IFLOWS indicated 5 to 6 inches in about a 6-hour period. This caused Jennings Creek to flood Routes 614, 618 and 620.

06/06/05 - An isolated strong storm developed over parts of eastern Roanoke and southeast Botetourt counties on the evening of June 6, producing flooding along parts of Glade Creek. An IFLOWS gage at Glade Creek (GLEV2) recorded 2.25 inches in less than 3 hours. Radar indicated up to 3 inches per hour over a local area, up to 4 inches ABR for most of the Glade Creek headwater basins, and 5 to 6 inches storm total for a small area. Glade Creek was reported out of its banks, and flooding was reported at Willow Brook Mobile Home Park.

Source: National Weather Service, Blacksburg office

Craig County

Past Small Stream/Flash Flooding

4/17/00 – Training thunderstorms brought 1.5 to 2.0 inches of rain in an hour to southeastern sections of Craig County, three-hour totals of 2.0 to 2.5 inches, and six-hour totals of 3.0 to 4.0 inches. This caused Broad Run to flood and close State Route 618.

5/22/01 – Radar estimated 0.75 to 1.0 inches of rainfall across eastern sections of the county. However, co-op reports indicate the rainfall was probably 1.0 to 1.25 inches. The rain fell in less than an hour. This caused Potts and Johns Creeks to come out of their banks, but only minor flooding. No roads were closed, but Potts Creek near Paint Bank washed out the shoulder of one road.

6/5/01 – Radar estimated a large area of rainfall of 3 to 4 inches across a section of eastern Craig and western Botetourt counties in the National Forest. Nearby IFLOWS indicate the estimate was probably good, and that rainfall rates were as high as 1.2 inches in 30 minutes. This caused flooding and washout damage to Rte 606 in both counties (gravel road), and flash flooding along Broad Run Creek in Craig County

2/23/03 – Strong dynamics associated with cyclogenesis and a slow moving cold front brought 0.5 to 1.0 inch of rain ending 22/12z, and then about a 6 hour period of heavy rain of around 2.0 inches between 22/12z and 22/18z. 12-hour rainfall totals were 2.5 to 3.0 inches. This caused Craig Creek to come out of its banks, but only closed Rte 621 in the Webbs Mill area briefly. Johns Creek flooded, but did not close any roads. Potts Creek washed out a culvert pipe at Rte 311 in Paint Bank and caused some road shoulder damage.

Source: National Weather Service, Blacksburg office

Franklin County, VA

Past Small Stream/Flash Flooding

6/24/95 - Up to 4 inches in less than 6 hours, (on saturated ground), washed out a culvert on State Rt 652 east of Snow Creek and made a 25 foot deep hole. 3 people were killed when a truck ran into the hole. Gills Creek flooded State Rt 657 east of Boones Mill near Red Valley. State Rt 670 near Smith Mtn Lake was flooded.

Franklin County, VA Past Small Stream/Flash Flooding continued

2/4/98 - 1 inch in 3 hours, 1.5 inches, in 6 hours, then a total of 2.0-2.25 inches in 9 hours caused Snow Creek to flood and knocked down a telephone pole near the community of Snow Creek. Also- several roads were blocked due to high water in the northwest part of the county (no specifics). FFG: 2.3 in 3 hours, 2.4 in 6 hours, and 2.7 in 12 hours.

8/23/99 - 4 inches of rain in about 2 hours caused minor flooding along backroads in northwest Franklin county in the Cahas Mountain area. FFG: 3.0 in 1 hour, and 5.0 in 3 hours.

8/23/99 - 3.5 to 4inches of rain in an hour and 15 minutes caused Story Creek (15), to flood US 40, and State Route 864 between Ferrum and Waidsboro. Town Creek (5), also flooded State Route 837. FFG: 3.0 in 1 hour, and 5.0 in 3 hours.

4/17/00 - Afternoon thunderstorms brought 1.0 to 1.5 inches of rain, and then a cluster of thunderstorms three to four hours later in the evening brought a 6-hour total of 3.0 to 3.5 inches. This caused small creek and street flooding (16) in the Rocky Mount area. FFG: 1.7 in one hour, 2.2 in three hours, and 2.4 in six hours.

8/1/00 - Quasi-stationary regenerating thunderstorms over northern Franklin county brought radar estimated rainfall of 5.6 inches in about a 6 hour period, with rates of around an inch per hour. This caused flash flooding along Maggodee Creek (1) from Naff, through the Boones Mill area. This also caused flooding along State Rt 641 at the confluence of the North and South Forks of the Blackwater river (3). US 220 was closed 1 mile north of Boones Mill with mudslides and 2 feet of water covering the roads. Buck Run (16) flooded State Rt 731. FFG: 1.6 in one hour, 2.0 in three hours, and 3.2 in six hours.

9/2/00 - Radar estimated 1.5 to 1.75 inches of rain in about an hour over the town of Rocky Mount (16). A stopped up culvert on Franklin St flooded the health department. FFG: 1.8 in 1 hour, and 2.4 in 3 hours.

9/3/00 - Radar estimated rainfall of 1.75 to 2 inches in about an hour in southeast Franklin county. This caused Guthrie Creek and Finneys Branch (17) to flood Rts 632 and 890. FFG: 1.7 in 1 hour, and 2.2 in 3 hours.

2/22/03 - Strong dynamics associated with cyclogenesis and a slow moving cold front brought 0.5 to 1.0 inch of rain ending 22/12z, and then about a 6 hour period of heavy rain of around 2.0 inches between 22/12z and 22/18z. 12 hour rainfall totals were around 2.5 inches. This caused the Blackwater River (13) to flood Rt 709 (Hopkins Rd/Blue Bend Rd) near Gogginsville. The USGS gage on the Blackwater River near Rocky Mount crested at 11.9 feet. FFG: 1.4 in 1 hr, 1.8 in 3 hrs, 2.0 in 6 hrs, and 2.3 in 12 hrs.

8/30/06 - Radar estimated rainfall of 2.5 inches in 1 hour, and a total of 3.5 inches in about 2 hours, caused Coopers Mountain Road and Sutton Hollow Road to flood in the **Snow Creek (17)** area, and Cooper Mountain Road was eventually washed out. FFG: 3.0 in 1 hour, and 4.9 in 3 hours.

Source: National Weather Service, Blacksburg office

Roanoke City/County

Past Small Stream/Flash Flooding

8/23/99 – Rainfall at a rate of 2 inches per hour, and a total of 5 to 6 inches in less than 3 hours, caused Bottom Creek, in extreme southern Roanoke County to come out of its banks and flood State Route 706. A section of county line road along the Roanoke/Floyd county border was also washed out.

9/5/99 – Rainfall at a rate of ½ inch an hour amounted to 2.5 inches in 6 hours, and 4.25 inches in 12 hours. This caused Mudlick Creek to come out of its banks near Edgewood St. and Brandon Rd.

04/17/00 - Training thunderstorms brought 1.5 to 2.0 inches of rain in an hour to northern and eastern sections of Roanoke County, 3-hour totals 2.0 to 2.5 inches, and 6-hour totals of 3.0 to 4.0 inches. This caused Masons Creek and the West Fork of Carvin Creek to overflow their banks. Carvin Creek flooded parts of Brookside Golf Course near Plantation Rd. Tinker and Glade Creeks were out of their banks in the town of Vinton, closing Wise Avenue. Significant street flooding was reported in the City of Roanoke.

07/29/00 - A cluster of thunderstorms over Roanoke caused flash flooding across southern sections of the city. Heavy rain extended later in the evening into Vinton. The heavy rainfall occurred in about a 2-hour period. Radar estimated 2.5 to 3 inches, and there were spotter reports of 3.5 inches. Street flooding occurred on I-581 and US 220. Flash flooding along Murray Run flooded Brambleton Avenue and Lakewood Park. Flash flooding along Ore Branch flooded parts of Franklin Rd, particularly the Ramada Inn at the intersection of Brandon Avenue and Franklin Rd. Flooding occurred at the intersection of Tinker and Glade Creeks in Vinton.

8/01/00 - Quasi-stationary regenerating thunderstorms over southeast Roanoke County brought radar estimated rainfall of 5.6 inches in about a 6-hour period, with rates of around an inch per hour. This caused Back Creek to flood, which closed such roads as Back Rd, Starlight Lane, Starkey Rd, and Willow Branch Rd. There were also mudslides on US 220.

2/22/03 - Strong dynamics associated with cyclogenesis and a slow moving cold front brought 0.5 to 1.0 inch of rain ending 22/12z, and then about a 6-hour period of heavy rain of around 2.0 inches between 22/12z and 22/18z. 12-hour rainfall totals ranged from 2.5 to around 3.0 inches. This caused flooding all along the Roanoke River through the county and into the city at the Walnut Street gage. Walnut Street crested at 15.57 feet, nearly 6 feet above flood stage. The Willow River Apartments flooded the first floors of 12 buildings. Tinker Creek flooded in Vinton, closing Wise Avenue where there was one fatality when a truck went around a barricade and was swept into Tinker Creek. Back Creek flooded Back Road.

06/06/05 - An isolated strong storm developed over parts of eastern Roanoke and southeast Botetourt counties on the evening of June 6, producing flooding along parts of Glade Creek. An IFLOWS gage at Glade Creek (GLEV2) recorded 2.25 inches in less than 3 hours. Radar indicated up to 3 inches per hour over a local area, up to 4 inches ABR for most of the Glade Creek headwater basins, and 5 to 6 inches storm total for a small area. Glade Creek was reported out of its banks in the town of Vinton. Substantially less rainfall, estimated at 1 to 2 inches by radar produced flooding on Ore Branch in Roanoke flooding Brandon Avenue, the parking lots and grounds of George's Florist, and the Ramada Inn.

06/27/05 - Radar estimated up to 2 inches of rain in less than an hour fell in the Ore Branch basin. This caused significant urban flooding along Ore Branch, with water covering several roads and intersections in the vicinity of the stream and evacuations from the Ramada Inn.

Source: National Weather Service, Blacksburg office

Appendix B

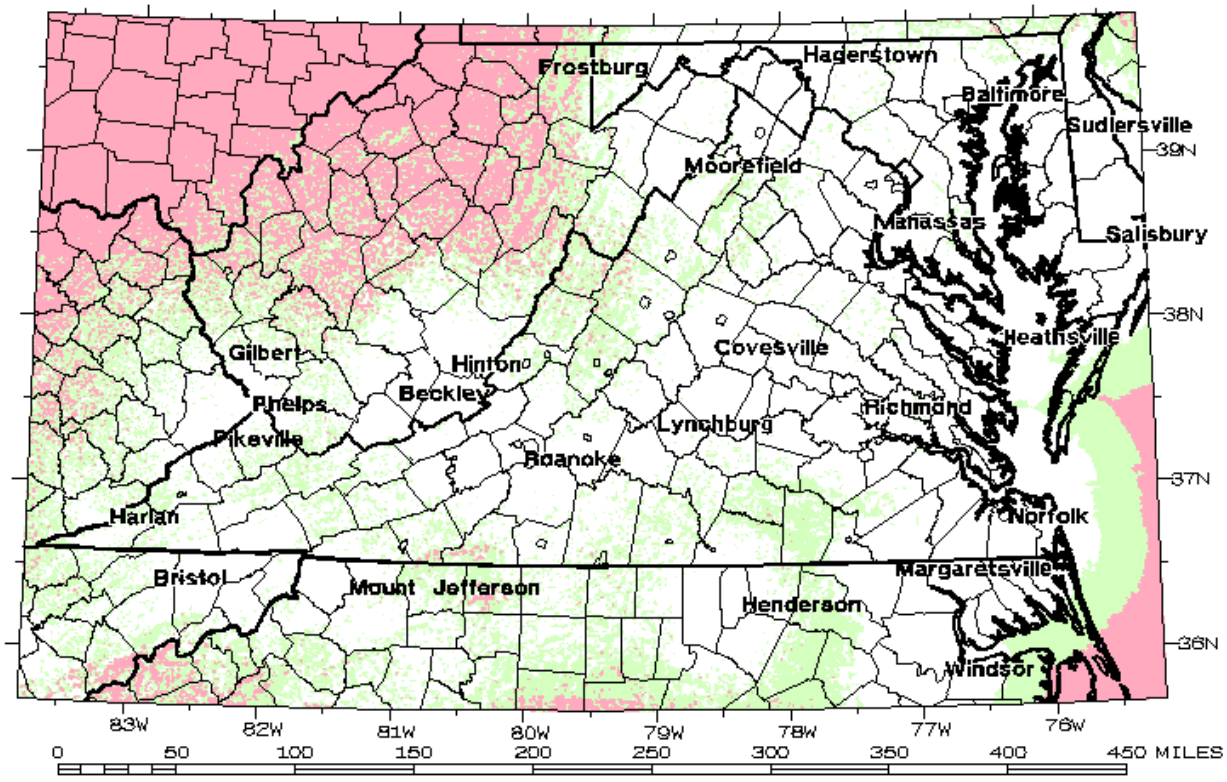
NOAA Weather Radio All Hazards
County Coverage

NOAA Weather Radio All Hazards
County Coverage

COUNTY/CITY/AREA	SAME #	NWR TRANSMITTER	FREQ.	CALL SIGN	WATT
Alleghany	051005	Hinton, WV	162.425	WXM72	1000
Alleghany	051005	Roanoke	162.475	WXL60	1000
Botetourt	051023	Roanoke	162.475	WXL60	1000
Clifton Forge	051560	Hinton, WV	162.425	WXM72	1000
Clifton Forge	051560	Roanoke	162.475	WXL60	1000
Covington (city)	051580	Hinton, WV	162.425	WXM72	1000
Covington (city)	051580	Roanoke	162.475	WXL60	1000
Craig	051045	Hinton, WV	162.425	WXM72	1000
Craig	051045	Roanoke	162.475	WXL60	1000
Franklin	051067	Roanoke	162.475	WXL60	1000
Roanoke	051161	Roanoke	162.475	WXL60	1000
Roanoke (city)	051770	Roanoke	162.475	WXL60	1000
Salem (city)	051775	Roanoke	162.475	WXL60	1000

Source: http://www.weather.gov/nwr/CntyCov/nwrVA.htm

NOAA Weather Radio sites



The coverage maps are shown in a three-color format, which relates to three estimated signal levels:

- White: Signal level of greater than 18dBuV: Reliable coverage
- Green: 0dBuV to 18dBuV: picking up a signal is possible but unreliable
- Red: Less than 0dBuV: Unlikely to receive a signal

Source: http://www.nws.noaa.gov/nwr/states/virginia.html

Appendix C

Rain Gauge and Stream Gauge Locations

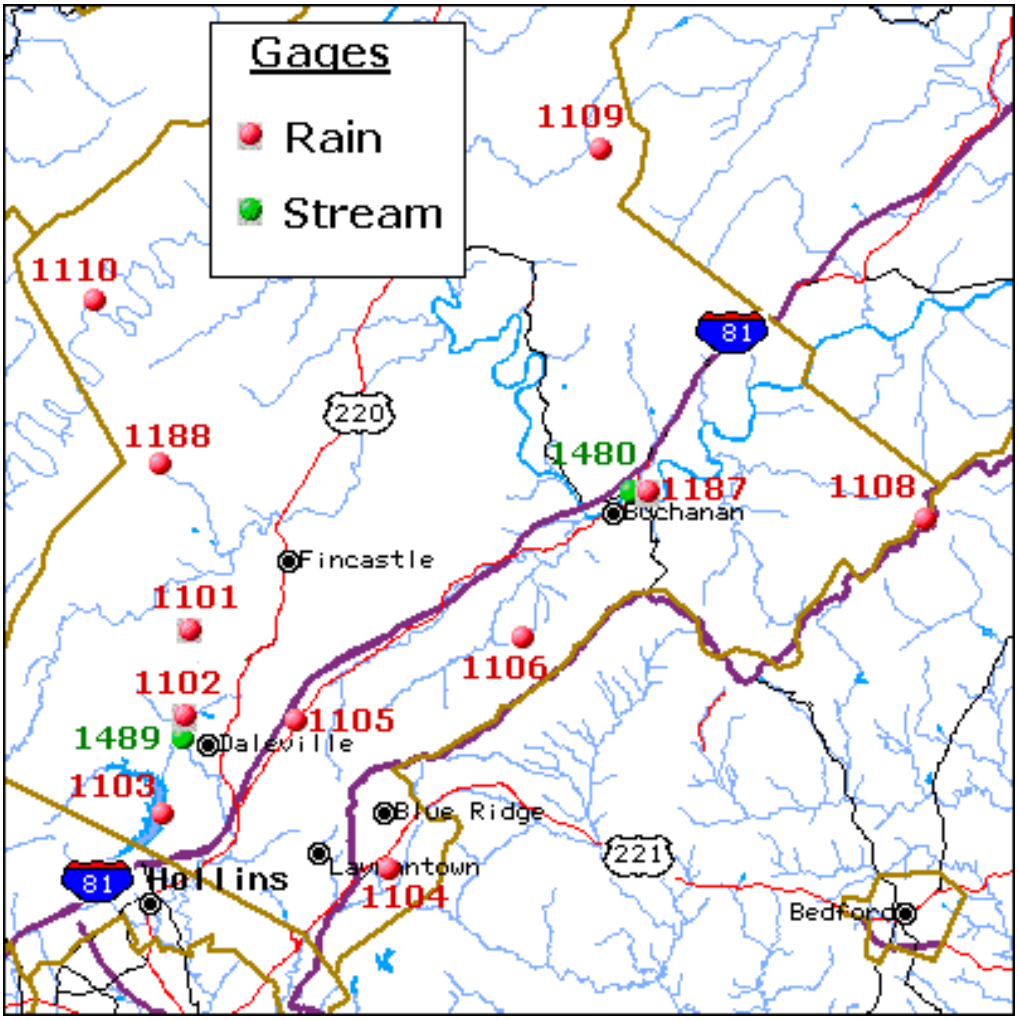
Botetourt County

Rain Gauge Locations

Gauge Name	ID Number
Tinker Creek	1101
Daleville	1102
Carvin Creek	1103
Glade Creek	1104
Troutville	1105
Lithia	1106
Apple Orchard Mt	1108
Sloan Branch	1109
Oriskany	1110
Buchanan	1187
North Fork	1188

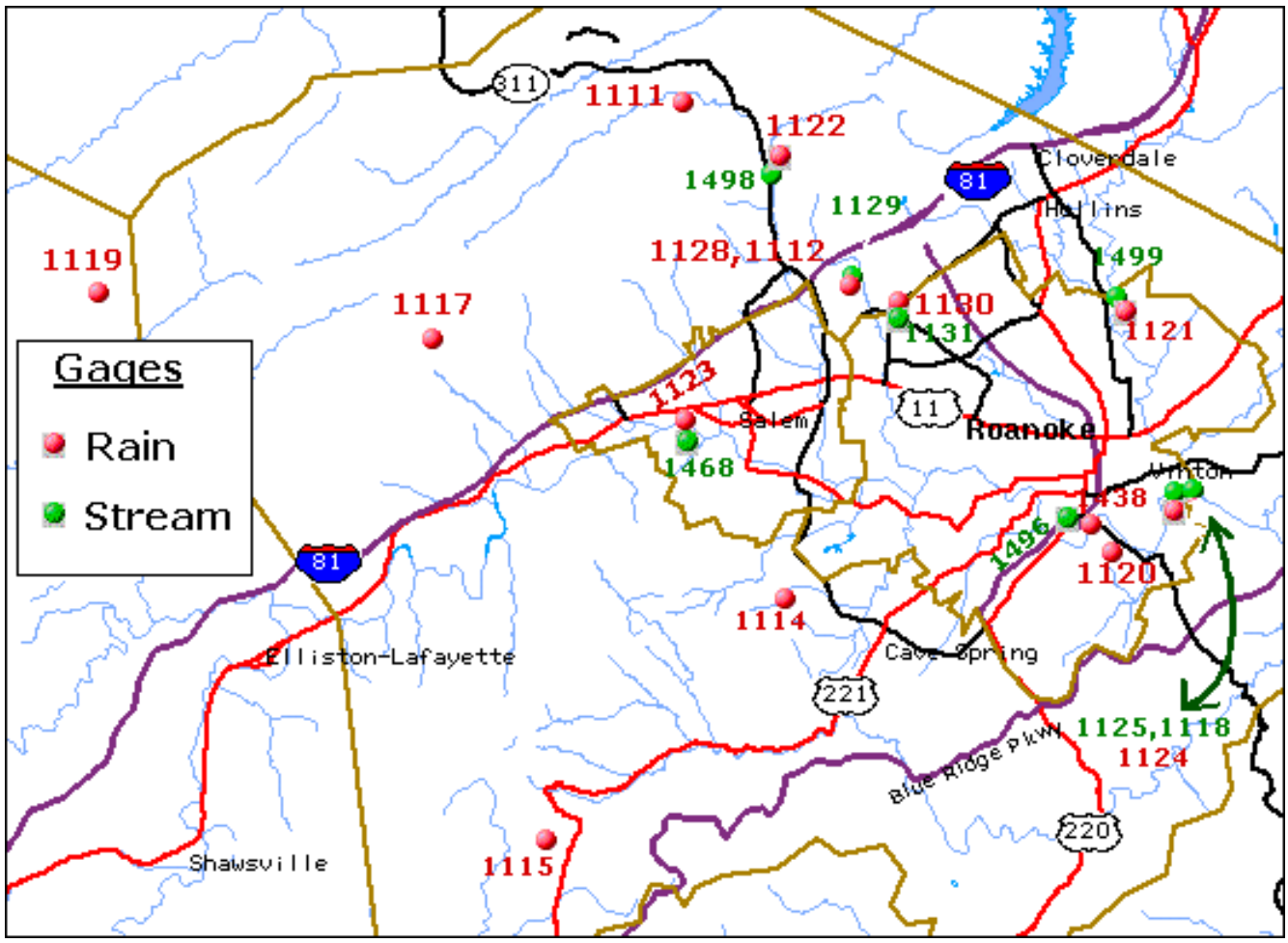
Stream Gauge Locations

Gauge Name	ID Number
Buchanan SG	1480
Daleville SG	1489


Gages
Rain
Stream
1109
1110
1188
1480
1187
1108
Buchanan
Fincastle
1101
1106
1102
1105
1489
Daleville
1103
Blue Ridge
Hollins
1104
Bedford
81
220
221

Roanoke City /Roanoke County

Gage Name	ID Number
Mason Cove	1111
Peters Creek	1112
Sugarloaf Mtn.	1114
Witt's Orchard	1115
Fort Lewis Mtn	1117
Crawfords Ridge	1119
Mill Mountain	1120
Tinker Creek S.	1121
Mason Creek	1122
Salem Pump Sta.	1123
Roanoke Sewer Plant	1124
Montclair	1128
Lower N. Lakes	1130
Walnut Street	1438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Rain
Stream
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1122
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1129
81
Cloverdale
Hollins
1119
1128,1112
1499
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1130
1131
1121
1123
11
Salem
Roanoke
1468
Vinton
1438
1496
1120
81
1114
Elliston-Lafayette
Cave Spring
221
1125,1118
1124
Blue Ridge Pkwy
220
Shawsville
1115

Bibliography

Southeast Regional Climate Center. 2005. Historical Climate Summaries for Virginia. Retrieved November 15, 2006 from http://cirrus.dnr.state.sc.us/cgi-bin/sercc/cliMAIN.pl?va7285.

Federal Emergency Management Agency. 2006. Retrieved November 17, 2006 from http://www.noaa.gov/floods.html.

Fifth Planning District Commission. 1999. *Rural Flood Prone Roadway Study*. Roanoke, Virginia.

National Weather Service, Office of Climate, Water, and Weather Services. 2004. *2004 Flash Flood / River Flood Related Fatalities.* Retrieved November 17, 2006 from http://www.weather.gov/os/severe_weather/flood04.pdf.

City of Roanoke Solid Waste Division. 2006. Leaf Collection Program. Retrieved November 21, 2006 from http://www.roanokeva.gov/WebMgmt/ywbase61b.nsf/CurrentBaseLink/N255ZRNJ153JEASEN

City of Roanoke Transportation Division. 2006. Retrieved November 21, 2006 from http://www.roanokeva.gov/WebMgmt/ywbase61b.nsf/CurrentBaseLink/N25FGK56338CFIREN

City of Roanoke. 2003. *Urban Forestry Plan.* Retrieved November 21, 2006 from http://www.roanokeva.gov/WebMgmt/ywbase61b.nsf/CurrentBaseLink/52B7BBA928679290852571A7004D979F/$File/Urban%20Forestry%20Plan.pdf.

Virginia Department of Emergency Management. Integrated Flood Observing and Warning System. Retrieved December 1, 2006 from http://www.vaemergency.com/programs/iflows/index.cfm

City of Roanoke. *Community Hazards Analysis.* Retrieved January 25, 2007 from http://www.roanokeva.gov/WebMgmt/ywbase61b.nsf/vwContentByKey/N255HTFQ923DLANEN

Natural Resources Defense Council. Stormwater Strategies - Community Responses to Runoff Pollution, Chapter 12, Low Impact Development. Retrieved November 28, 2006 from http://www.nrdc.org/water/pollution/storm/chap12.asp.