



Flood Mitigation Report West Branch Delaware River SD 060


Delaware County, New York
January 2021

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ABBREVIATIONS/ACRONYMS

BFE	Base Flood Elevation
BIN	Bridge Identification Number
CFS	Cubic Feet per Second
CMP	Corrugated Metal Pipe
CRS	Community Rating System
CSM	Cubic feet per second per square mile
DCSWCD	Delaware County Soil and Water Conservation District
DRBC	Delaware River Basin Commission
DRM	Delaware River Master
EBDR	East Branch of the Delaware River
EWP	Emergency Watershed Protection
FEMA	Federal Emergency Management Agency
FFMP	Flexible Flow Management Program
FIRM	Flood Insurance Rate Map
FIS	Flood Insurance Study
FMA	Flood Mitigation Assistance
FPMS	Floodplain Management Services Program
FUDR	Friends of the Upper Delaware River
GIS	Geographic Information System
HEC-RAS	Hydrologic Engineering Center – <i>River Analysis System</i>
HMGP	Hazard Mitigation Grant Program
HMP	Hazard Mitigation Plan
HSG	Hydrologic Soil Group
LOMC	Letter of Map Change
MMI	Milone & MacBroom, Inc.
MWRR	Municipal Waste Reduction and Recycling
NBI	National Bridge Inventory

NFIP	National Flood Insurance Program
NFIRA	National Flood Insurance Reform Act
NOAA	National Oceanic and Atmospheric Administration
NRCS	Natural Resources Conservation Service
NWI	National Wetlands Inventory
NYCDEP	New York City Department of Environmental Protection
NYS	New York State
NYSDEC	New York State Department of Environmental Conservation
NYSDOT	New York State Department of Transportation
NYSEG	New York State Electric and Gas
NYSOGS	New York State Office of General Services
NYSW	New York Susquehanna & Western Railway Corp.
OGS	Office of General Services
PDM	Pre-Disaster Mitigation
RCP	Representative Concentration Pathways
RFC	Repetitive Flood Claims
SFHA	Special Flood Hazard Area
SIR	Scientific Investigations Report
SRL	Severe Repetitive Loss
STC	Sediment Transport Capacity
UDRTC	Upper Delaware River Tailwaters Coalition
USACE	United States Army Corps of Engineers
USGS	United States Geological Survey
WBDR	West Branch of the Delaware River

1.0 INTRODUCTION

1.1 Project Background and Overview

The West Branch of the Delaware River (WBDR) originates in the town of Stamford in Delaware County and flows south and west through the villages of Delhi and Walton before entering the Cannonsville Reservoir, which is operated by the New York City Department of Environmental Protection (NYCDEP) as part of the west-of-Hudson water supply system for New York City. Downstream of the Cannonsville Reservoir, the WBDR turns to the south and east, joining the East Branch in the village of Hancock to form the Delaware River along the New York/Pennsylvania state line.

Historically, flooding has been the greatest threat from natural disasters in Delaware County. Recent widespread flooding in the WBDR valley has occurred in 2011, 2007, 2006, 2005, 2004, and 1996 although severe localized flooding is a relatively frequent occurrence on tributary streams in the basin. This study focuses on flooding within the tailwater section of the WBDR, which extends 18.5 river miles from the outlet of the Cannonsville Reservoir downstream to its confluence with the East Branch in Hancock. This includes the towns of Deposit, Sanford, and Hancock. Tailwater refers to waters located downstream of a hydraulic structure, in this case the dam at the Cannonsville Reservoir.

This work is a component of the Resilient New York Program, an initiative of the New York State Department of Environmental Conservation (NYSDEC), contracted through the New York State Office of General Services (NYSOGS). The goal of the Resilient New York Program is to make New York State more resilient to flooding and climate change. Through the program, flood studies are being conducted across the state, resulting in the development of flood and ice jam hazard mitigation alternatives to help guide implementation of mitigation projects.

This report begins with an overview of the WBDR channel and watershed, summarizes the history of flooding, and identifies flood-prone communities along the WBDR. An analysis of flood mitigation considerations within each flood-prone community is undertaken. Factors with the potential to influence more than one WBDR community, such as the attenuating effect of the Cannonsville Reservoir on downstream peak flows and the behavior of channel sediment, are also evaluated and discussed. Flood mitigation recommendations are provided either as community-specific recommendations or as overarching recommendations that apply to the entire WBDR watershed or stream corridor. For each flood-prone community, a relocation master plan is provided. The relocation plans are intended to be used on a voluntary basis by the county, municipalities, and by individual property owners to guide potential relocation efforts out of and away from flood-prone areas. An emphasis was placed on locating suitable sites within the same communities. Flood mitigation scenarios such as levee enhancement, sediment management, floodplain enhancement and channel restoration, road closures, and replacement of undersized bridges are investigated and are recommended where appropriate.

1.2 Terminology

The West Branch of the Delaware River is abbreviated throughout this report as the WBDR. The East Branch of the Delaware River is similarly abbreviated as the EBDR.

In this report, all references to right bank and left bank refer to "river right" and "river left," meaning the orientation assumes that the reader is standing in the river looking downstream.

In this report and associated mapping, stream stationing is used as an address to identify specific points along the watercourse. Stationing is measured in miles and begins at the confluence of the WBDR and EBDR at station (STA) 0.0 and continues upstream to STA 18.4 at the Cannonsville Reservoir. As an example, the Route 56 bridge over the WBDR in Hale Eddy is located at approximately STA 9.7, meaning that it is 9.7 miles upstream of the confluence in Hancock.

The Federal Emergency Management Agency (FEMA) is an agency of the United States Department of Homeland Security. In order to provide a common standard, FEMA's National Flood Insurance Program (NFIP) has adopted a baseline probability called the base flood. The base flood has a 1 percent (one in 100) chance of occurring in any given year, and the base flood elevation (BFE) is the level floodwaters are expected to reach in this event. For the purpose of this report, the 1 percent annual chance flood is also referred to as the 100-year flood. Other recurrence probabilities used in this report include the 2-year flood event (50 percent annual chance flood), the 10-year flood event (10 percent annual chance flood), the 25-year flood event (4 percent annual chance flood), the 50-year flood event (2 percent annual chance flood), and the 500-year flood event (0.2 percent annual chance flood).

The Special Flood Hazard Area (SFHA) is the area inundated by flooding during the 100-year flood event. Within the project area, FEMA has developed Flood Insurance Rate Mapping (FIRM), which indicates the location of the SFHA along the WBDR and several of its tributaries.

2.0 DATA COLLECTION

Data were gathered from various sources related to the hydrology and hydraulics of the WBDR and its tributaries, WBDR watershed characteristics, recent and historical flooding in the affected communities, and factors that may contribute to additional flood hazards.

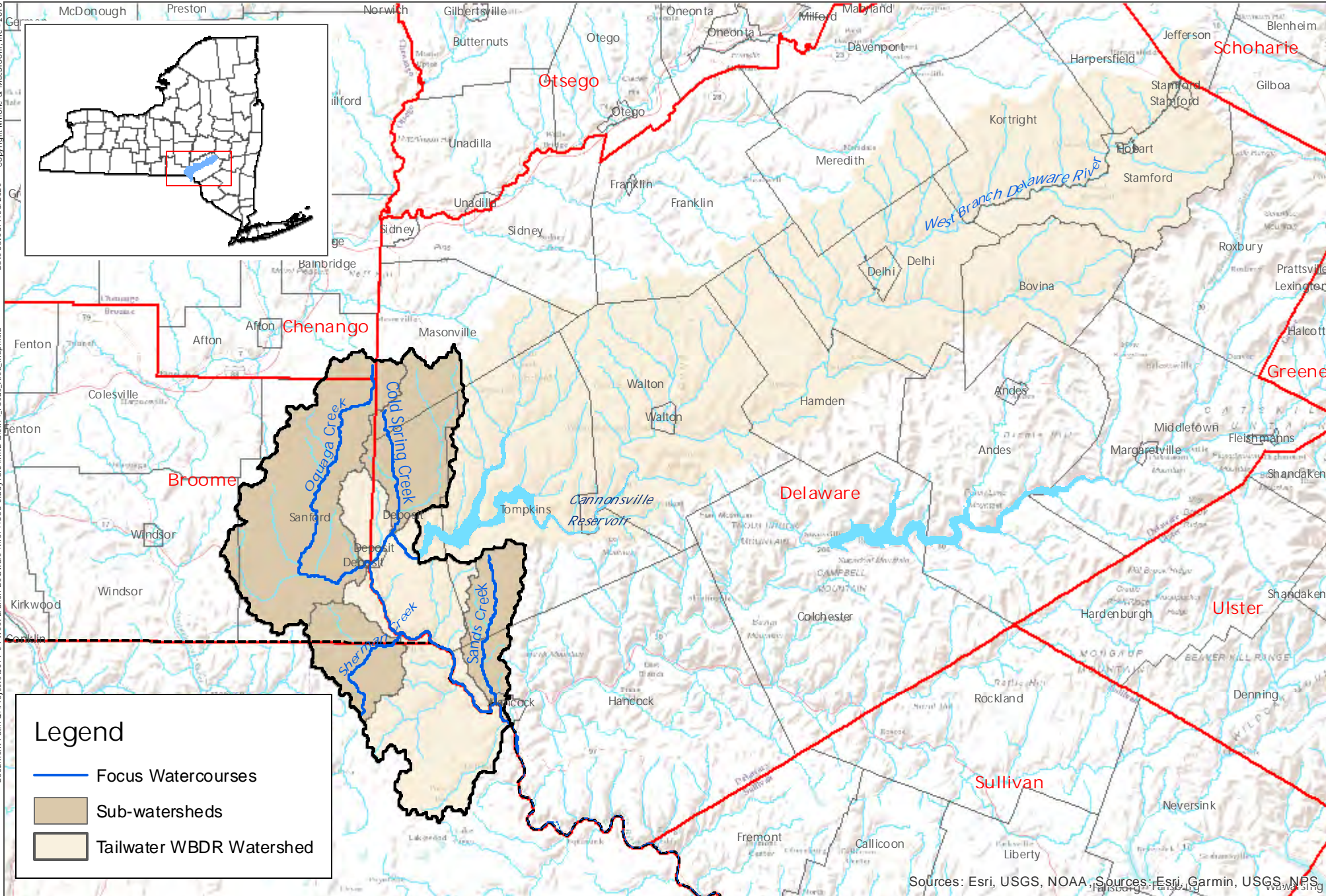
2.1 Watershed

The WBDR watershed is located in the Northern Appalachian Plateau physiographic region of New York State. The watershed drains in a southwesterly direction, draining southern Delaware County, northern Sullivan County, and a portion of western Ulster County, including part of the Catskill Mountains. The entire watershed is underlain by Devonian clastic sedimentary bedrock, predominantly composed of sandstones, shales, and conglomerates. The bedrock geology has been mapped as the Upper Walton Formation in the valleys while the ridges and peaks are predominantly mapped as the Honesdale Formation. The Slide Mountain formation lies between the two. All three belong to the West Falls Group. The Middle-Upper Devonian Oneonta Formation and other constituents of the Genessee Group are encountered farther upstream in the valley. Areas of shallow or exposed bedrock occur at higher elevations. Surficial materials consist primarily of glacial drift, including till, outwash, and periglacial deposits, with alluvial and semialluvial secondary deposits of drift material in the valley bottoms.

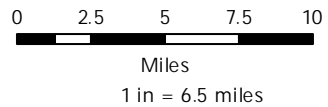
The WBDR watershed, measured at its confluence with the EBDR in Hancock, comprises 665 square miles. An area of 454 square miles, or 68 percent of the WBDR watershed, is located upstream of the dam at the Cannonsville Reservoir while the remaining 211 square miles, or 32 percent, are located downstream of the dam. Major tributaries to the tailwater section of the WBDR include Cold Spring Creek, Oquaga Creek, Sherman Creek, and Sands Creek. These are listed in Table 2-1 along with their respective watershed areas. Note that several tributaries to the WBDR drain from Wayne County, Pennsylvania. Figure 2-1 is a watershed map of the WBDR with the tailwater section highlighted.

TABLE 2-1
Subwatersheds within the Tailwater Section of the WBDR Watershed

WBDR Tributary	Subwatershed Size (square miles)
Cold Spring Creek	30.7
Oquaga Creek	67.5
Sherman Creek	19.2
Sands Creek	17.6



WBDW FOCUS WATERSHEDS
 WEST BRANCH DELAWARE RIVER FLOOD STUDY - SD061
 FIGURE 2-1



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During a rainfall event, the proportion of rainfall that runs off directly into rivers and streams or that infiltrates into the ground is greatly influenced by the composition of soils within a watershed. Soils are assigned a hydrologic soil group (HSG) identifier, which is a measure of the infiltration capacity of the soil. These are ranked A through D. An HSG A soil is often very sandy, with a high infiltration capacity and a low tendency for runoff except in the most intense rainfall events; a D-ranked soil often has a high silt or clay content or is very shallow to bedrock and does not absorb much stormwater but instead is prone to runoff even in small storms. A classification of B/D indicates that when dry the soil exhibits the properties of a B soil, but when saturated, it has the qualities of a D soil. Over 85 percent of the mapped soils in the WBDR watershed are classified as HSG C, C/D, or D, indicating a low capacity for infiltration and high tendency for runoff (Figure 2-2). This contributes to flash flooding in the watershed as rainfall runoff moves swiftly into streams rather than gradually seeping through the soils. This is mitigated to some degree by the large areas of forest in the watershed, which tend to encourage infiltration and reduce runoff.

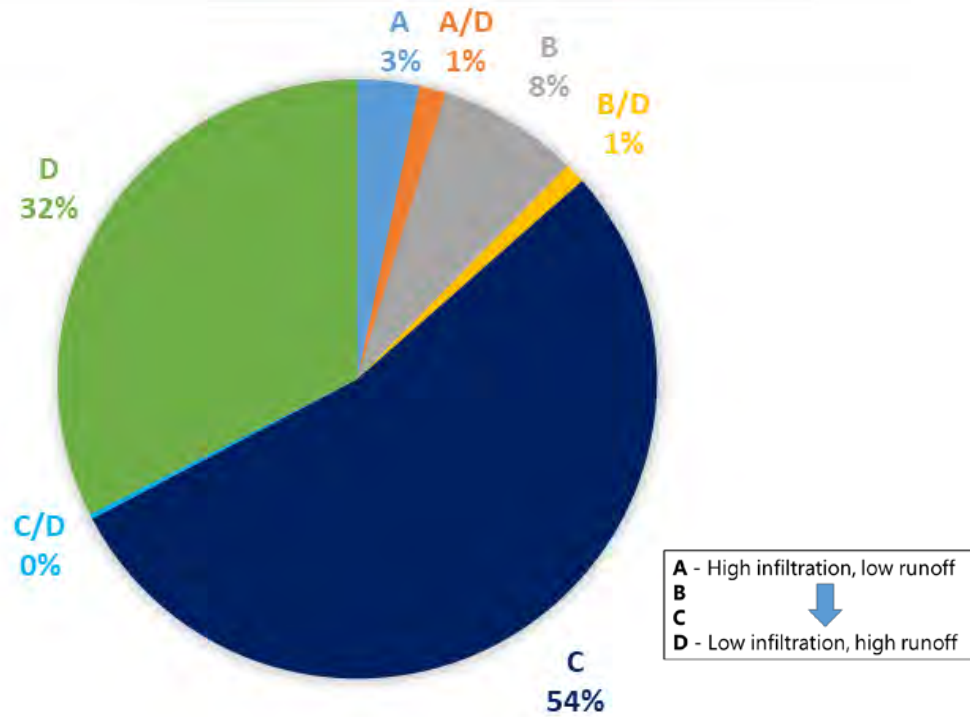


Figure 2-2: Hydrologic Grouping of Soils within the WBDR Watershed

Land cover within the WBDR watershed can be characterized using the 2016 Multi-Resolution Land Characteristics National Land Cover Database for Southeast New York State (Figure 2-3). Forested land consists of deciduous, coniferous, and mixed forest types and makes up 73 percent of the land cover in the watershed. Agricultural lands, including hay, pasture, and cultivated crops, make up 17 percent. Developed land represents 5 percent of the land cover. The remaining 5 percent of the land cover consists of grassland, shrubland, wetlands, open water, and barren land.

Wetland cover was also examined using information available from the U.S. Fish and Wildlife Services' National Wetlands Inventory (NWI). The NWI indicates that there are 11,902 acres of wetlands in the WBDR watershed, or approximately 2.7 percent of the watershed. This is a greater area of wetlands compared to the amount estimated based on land cover and includes the following types of wetland habitats: freshwater forest/shrub wetland, freshwater emergent wetland, freshwater pond, lake (reservoirs), riverine, and other wetland types. It is estimated that since colonial times approximately 50 to 60 percent of the wetlands in the state of New York have been lost through draining, filling, and other types of alteration. In the Upper Delaware River basin, some wetland fill was composed of quarry waste and rock dust produced by the bluestone industry.

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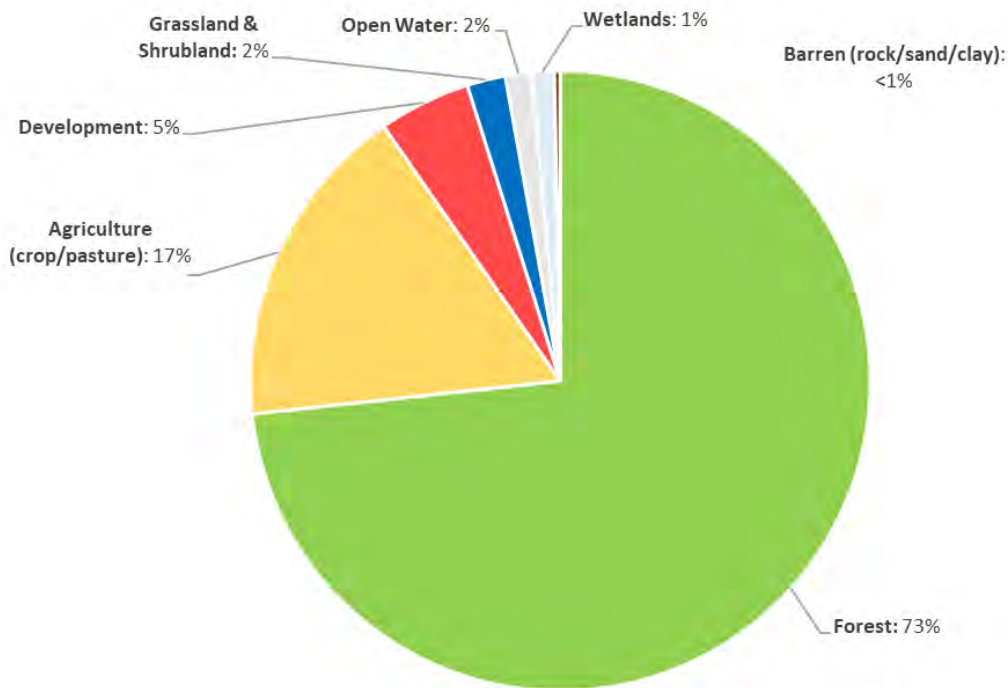


Figure 2-3: Land Cover within the WBDR Watershed

2.2 WBDR Watercourse

The WBDR flows through a confined valley, which was scoured by glaciers during the Pleistocene era, then partially refilled with glacial drift and meltwater outwash deposits during the late Pleistocene and early Holocene glacial retreat. A critical consequence is that the active alluvial regime of the WBDR exists within a valley that has primarily been shaped by glacial processes. The WBDR and its tributaries are actively resculpting the landscape into a balance with the fluvial morphological processes that now dominate, a progression that occurs over millennial timescales and has yet to reach an equilibrium. In recent centuries, widespread and extensive anthropogenic

The active alluvial regime of the WBDR exists within a valley that has primarily been shaped by glacial processes. The WBDR and its tributaries are actively resculpting the landscape into a balance with the fluvial morphological processes that now dominate, a progression that occurs over millennial timescales and has yet to reach an equilibrium.

activity has also shaped the WBDR, its tributaries, and their valleys and floodplains. These modifications have taken place within the context of a highly active, unstable morphological regime and often oppose the river's natural evolution. Such modifications therefore require frequent maintenance, are rarely permanent, and foster the especially severe flooding damages that can occur when the streams undergo fluvial adjustment, either in profile, planform, or both.

The valley bottom ranges from a maximum width of 2,000 to 3,000 feet between Stilesville and Deposit to no more than several hundred feet at several points where the valley pinches down and the active channel occupies most of the valley width. The channel is broad and shallow with a flat bottom, which is typical of aggrading channels. Sediment bars have formed at all major confluences with the WBDR tributaries. This is typical of steep mountain streams entering flatter mainstems. Figure 2-4 shows the WBDR valley relief map.

The WBDR channel between the Cannonsville Reservoir and Hancock has a relatively mild slope, averaging 0.15 percent, or 7.9 feet per mile. Between Stilesville and Hancock, a number of steep-gradient tributaries drain into the WBDR. These tributaries have a cobble or boulder substrate and, while small in size, comprise a large percentage of the cumulative length of the WBDR watershed stream network. These tributaries can act as sediment and debris reservoirs wherein coarse sediment and wood are episodically transported to the WBDR channel through erosion and bank failures. These processes can be especially dramatic during flood events. Figure 2-5 depicts the longitudinal profile of the low-gradient WBDR along with the profiles of several steep-gradient tributaries. Encroaching development and infrastructure are susceptible to damage by flooding on the WBDR as well as these dynamic, highly energetic tributaries.

Stream order provides a measure of the relative size of streams by assigning a numeric order to each stream in a stream network. The smallest tributaries are designated as first-order streams, and the designation increases as tributaries join. The WBDR from near Delhi downstream to Hancock can be characterized as a sixth-order stream while the WBDR upstream of Delhi and several of the larger WBDR tributaries are fifth and fourth order. Many of the second- and first-order streams in the watershed are unnamed. Figure 2-6 is a map depicting stream order in the WBDR watershed.

Characteristics of each order of stream (total length, average slope, and percentage of overall stream network) are summarized in Table 2-2. First-, second-, and third-order streams cumulatively account for most of the overall stream length within the WBDR watershed (85 percent) and are much steeper in slope than fourth-, fifth-, and sixth-order streams.

Table 2-3 compares channel slope by stream order upstream and downstream of the Cannonsville Reservoir. Channel slopes of first- through third-order streams are somewhat steeper upstream of the reservoir.

TABLE 2-2
Stream Order Characteristics in the WBDR Watershed

Stream Order	Total Length (miles)	Percentage of Overall Network Length (%)	Average Slope (%)
1 st	456.8	44.7	5.5
2 nd	245.0	24.0	4.8
3 rd	163.6	16.0	3.3
4 th	70.7	6.9	1.6
5 th	42.3	4.1	0.6
6 th	43.9	4.3	0.4
Total	1,022.4	100	

TABLE 2-3
Comparison of Channel Slope by Stream Order above and below Cannonsville Reservoir

Stream Order	Average Slope Above Cannonsville Reservoir (%)	Average Slope Below Cannonsville Reservoir (%)
1 st	5.6	3.7
2 nd	5.0	3.2
3 rd	3.6	1.3
4 th	1.6	1.6
5 th	0.6	---
6 th	0.5	0.6

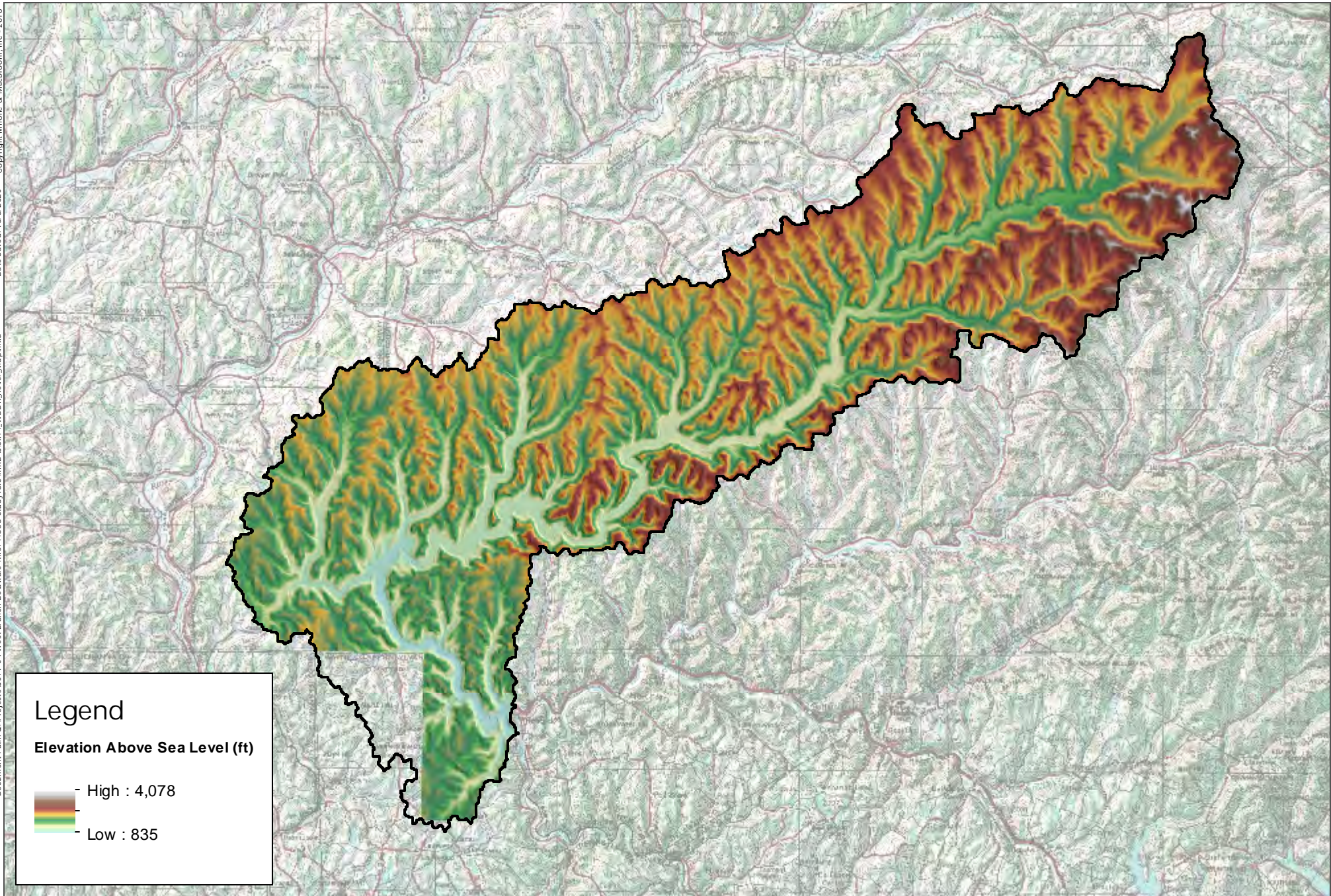
Eight bridges span the WBDR between the Cannonsville Reservoir and the confluence with the EBDR in Hancock. These vary in age and represent a variety of construction styles, as listed in Table 2-4. Most of the bridges span the estimated bankfull width of the channel although the Hale Eddy bridge spans slightly less than the estimate.

**TABLE 2-4
Bridges Spanning the WBDR between Hancock and the Cannonsville Reservoir**

Road	Location	River Station (miles)	NBI BIN**	Year Constructed	Bridge Condition	Span (feet) (number of spans)	Rise Above Thalweg (feet)	Bankfull Width* (feet)
Route 191	Hancock	1.3	1091700	1937	Fair	471.1 (2)	19.9	247
Route 56	Hale Eddy	9.7	3352290	2000	Good	235.9 (2)	23.4	239
Route 17 Eastbound	Deposit	14.4	1013332	1961	Fair	592.8 (6)	68	234
Route 17 Westbound			1013331	1961	Fair	629.9 (6)	68	234
NYSW Railway	Deposit	14.6				265 (2)	20.1	219
Oak St/ Pine St Ext	Deposit	14.9	1007640	1990	Good	232.9 (2)	21.2	219
Route 8	Stilesville	16.6	1007660	1990	Fair	535.1 (4)	23.7	212
NYCDEP Access Road	Stilesville	18.2				246 (5)	29	212

* Estimated bankfull width per United States Geological Survey (USGS) Scientific Investigations Report (SIR) 2009-5144

** NBI BIN – National Bridge Inventory Bridge Identification Number



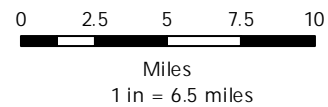
Legend

Elevation Above Sea Level (ft)

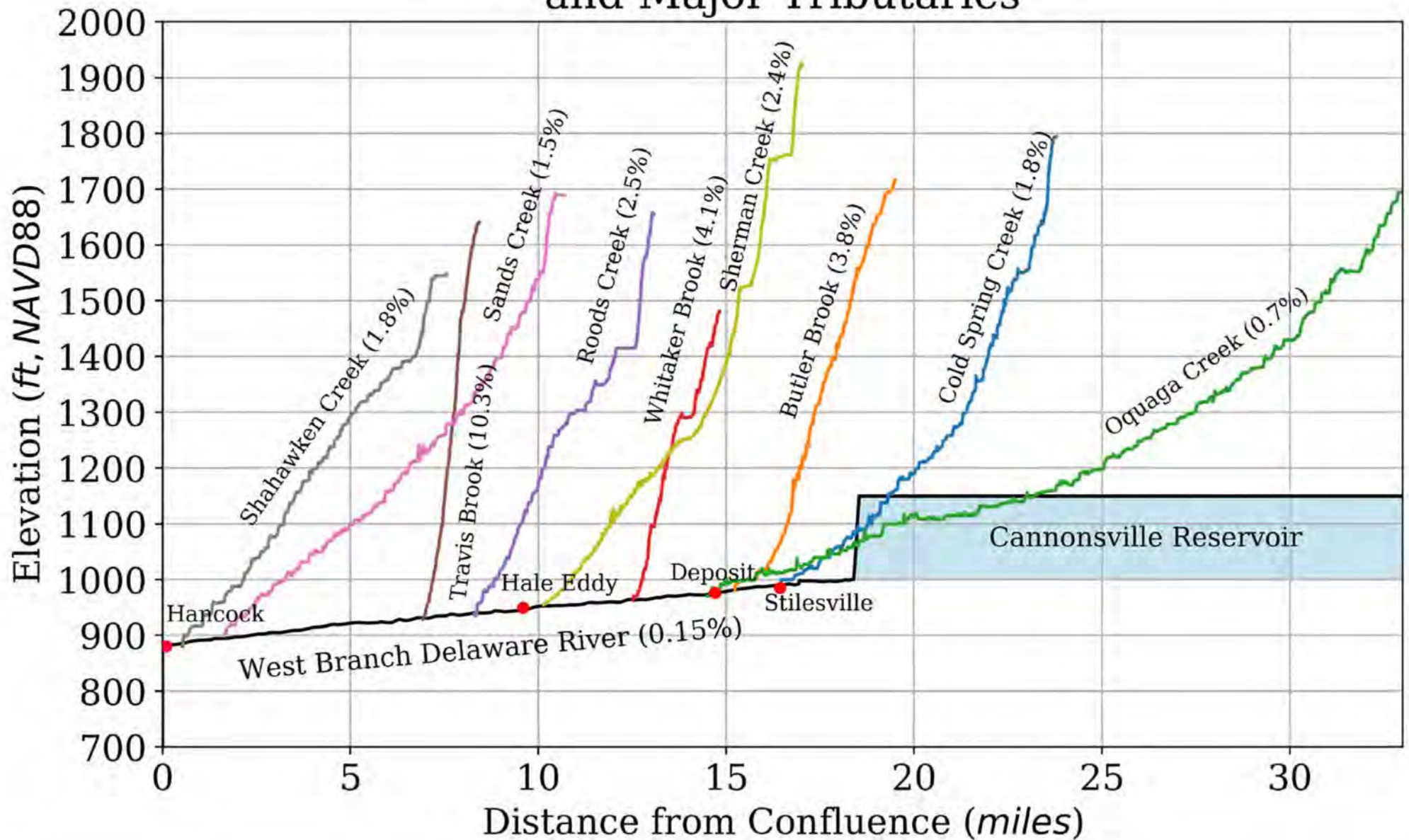
- High : 4,078

- Low : 835

WBDR RELIEF MAP
WEST BRANCH DELAWARE RIVER FLOOD STUDY - SD061
FIGURE 2-4



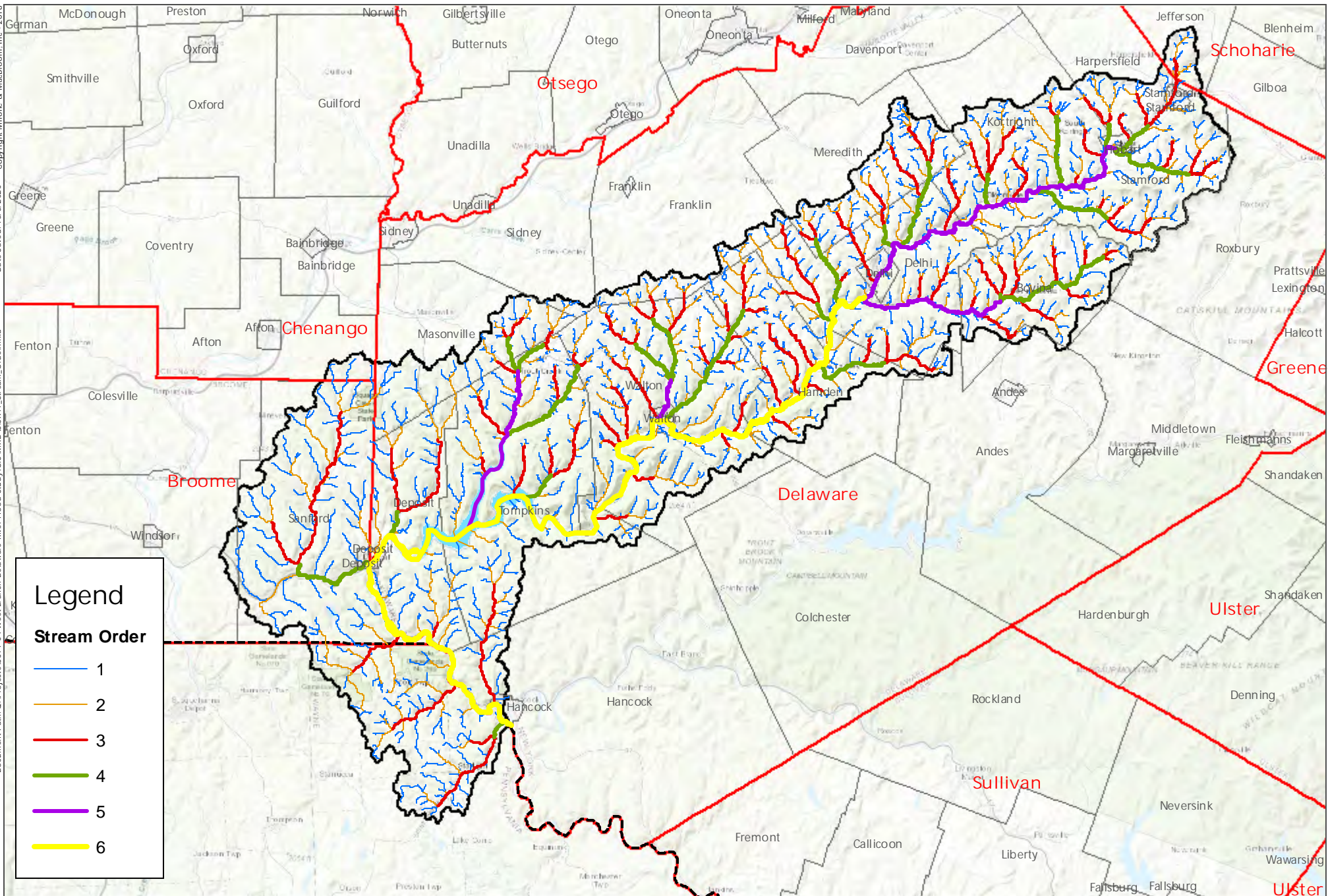
West Branch Delaware River Tailwaters and Major Tributaries



WBDR LONGITUDINAL PROFILE

WEST BRANCH DELAWARE RIVER FLOOD STUDY - DS061

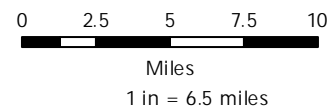
FIGURE 2-5



WBDR STREAM ORDER

WEST BRANCH DELAWARE RIVER FLOOD STUDY - SD061

FIGURE 2-6



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2.3 Hydrology

Hydrologic studies are conducted to understand historical, current, and potential future river flow rates, which are a critical input for hydraulic modeling software such as Hydrologic Engineering Center – *River Analysis System* (HEC-RAS). These often include statistical techniques to estimate the probability of a certain flow rate occurring within a certain period of time based on data from the past; these data are collected and maintained by the United States Geological Survey (USGS) at thousands of stream gauging stations around the country. For the streams without gauges, the USGS has developed region-specific regression equations that estimate flows based on watershed characteristics, such as drainage area and annual precipitation, as well as various techniques to account for the presence of nearby stream gauges or to improve analyses of gauges with limited records. These are based on the same watershed characteristics of gauged streams in that region so are certainly informative although not as accurate or reliable as a gauge due to the intricacies of each unique basin.

For the purposes of this study, we are primarily concerned with the more severe flood flows although hydrologic analyses may be conducted for the purposes of estimating low flows, high flows, or anywhere in between. The commonly termed "100-Year Flood" refers to the flow rate that is predicted to have a 1 percent, or 1 in 100, chance of occurring in any year. A "25-Year Flood" has a 1 in 25 chance of occurring (4 percent) every year. It is important to note that referring to a specific discharge as an "X-Year Flood" is a common and convenient way to express a statistical probability but can be misleading because it has no bearing whatsoever on when or how often such a flow actually occurs.

The WBDR watershed is relatively well gauged both in terms of density of stations and the long time periods during which many have been under continuous operation. However, these records represent a broad range of hydrologic conditions as the construction of the Cannonsville Reservoir and the reforestation of the WBDR's watershed have dramatically influenced the hydrology of the basin over the past several decades. Some stream flow gauge records in the WBDR watershed span a century, and considerable land use change has occurred over this time.

Most of the hillsides that were bare in the early 1900s, having been cleared for timber resources and agriculture or stripped for bluestone extraction, were substantially reforested by the close of the century. This succession has influenced the runoff response of the watershed, and a rainfall event of a given intensity and duration is likely to have produced significantly different peak discharges on the WBDR over these gauges' periods of record. The influence of changing land use patterns on flood magnitude over the years is difficult to untangle from the impacts of the Cannonsville Dam, which was constructed in the early 1960s, following a time period when the forestry and agricultural industries in the watershed had been in decline. Both the dam and these land use changes would generally act to reduce peak flood magnitude in the WBDR tailwaters by "flattening the curve" of the flood wave, assuming fixed meteorological and climatic conditions.

Estimated flood hydrology may be affected by the availability and quality of data and observations from the past and the methodology used to extrapolate from this information.

Actual flood flows can be affected by land use and soil characteristics, flow regulation, antecedent conditions, stream hydraulics, and climatic inputs like the intensity and duration of rainfall.

According to the USGS, control of the WBDR by the Cannonsville Dam began in October 1963. This date is used as a cutoff for statistical analyses of flood recurrence intervals performed on stream gauging data for the WBDR even when the records of those stations extend farther into the past. This approach is intended to isolate the current hydrological conditions from both the climate and the landscape of the past while retaining a sufficient period of record for statistical reliability. The beginning of flow regulation represents one of the greatest single changes to the WBDR's hydrology in hundreds or possibly thousands of years, effectively and abruptly establishing the river's current hydrologic regime. A limited assessment of the Cannonsville Reservoir's impact on flooding and flood attenuation in the WBDR tailwaters is presented in Section 4.1 of this report.

Along with the location, duration, and intensity of a storm, the flooding that may result from a rainfall event can vary widely depending on the unique hydrology of each basin. Characteristics of local topography, soils, vegetation cover and type, bedrock geology, land use and cover, river hydraulics and floodplain storage, ponding, wetland, and reservoir storage, combined with antecedent conditions in the watershed such as snow pack or soil saturation, can impact the timing, duration, and severity of flooding.

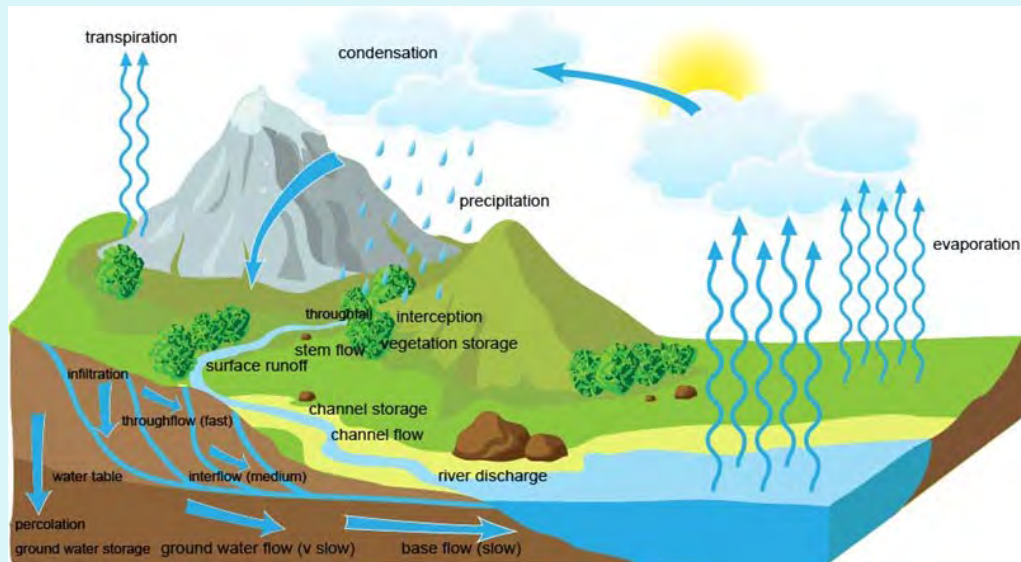


Figure 2-7: Diagram of Simplified Hydrologic Cycle

While the reservoir has undoubtedly had a substantial influence on flows and flooding on the WBDR, it is important to note that hydrologic analyses themselves can rapidly evolve over short periods of time. Statistical methods for determining flood return intervals are used to extrapolate the magnitude and frequency of flood events based on limited data sets. This enables the magnitude of the more severe floods to be estimated when often they have not been observed or recorded. The inclusion of recent extreme flood events on the WBDR has had a considerable impact on estimated peak flood discharges. Table 2-5 shows the influence of the flood events of 2004, 2005, 2006, and 2011 on the results of USGS Bulletin 17B gauge analysis of WBDR flows since construction of the Cannonsville Reservoir. These dramatic changes have occurred primarily due to four events over a short period of time, so even fairly recent hydrologic studies of the WBDR may have produced very different results than those computed based on the most current

data even when based on the same modern techniques. Such major changes in the results of hydrologic investigations may also result from advances in methodologies, growth of stream gauge record databases, or flow regulation and land use change as discussed above.

TABLE 2-5
Impact of Recent Flood Events on Estimated WBDR Flood Hydrology at Stilesville Gauge

Recurrence Interval (years)	Discharge 1963-2003 (cubic feet per second)	Discharge 1963-2019 (cubic feet per second)	% Change
500	28,500	45,300	+59
200	23,800	34,800	+46
100	20,500	28,100	+37
50	17,300	22,300	+29
25	14,300	17,300	+21
10	10,600	11,800	+11
5	7,900	8,300	+5
2	4,400	4,400	0

In the case of the WBDR, this is reflected in the substantial expansion of the SFHA between the last two Flood Insurance Studies (FIS). Tables 2-6 and 2-7 present the estimated peak flood flows on the WBDR near Deposit and at the Hale Eddy gauge, respectively, that were used in FEMA's 1979 and 2010 studies. These marked differences resulted in increases in computed BFEs of up to 9 feet or more in some locations along the WBDR. This and other increases or reductions in BFE from one FIS to the next can be due to updated hydrologic data as discussed above or can come from improvements in hydraulic modeling techniques. In other cases, changes in flood mapping may result from updated or refined topographic data, bridge replacements, or other physical changes to the river or floodplains, any of which can occur along with or independently of updates to flood hydrology. Such changes can be a source of confusion and frustration for residents who may be mapped into or out of the SFHA, as well as the local administrators who are tasked with enforcing floodplain regulations that affect the insurance premiums and property development requirements of others in the community.

TABLE 2-6
FEMA Estimated Peak Flows near Deposit

Recurrence Interval (years)	1979 Flood Insurance Study ¹ (cubic feet per second)	2010 Flood Insurance Study ² (cubic feet per second)	% Change ³
500	18,740	46,520	+167
100	14,900	32,110	+132
50	13,440	26,600	+113
10	10,330	15,300	+59

¹ Upstream corporate limits of village of Deposit – WBDR watershed area: 489 square miles

² Stilesville gauge – WBDR watershed area: 455 square miles

³ Percent change computed based on cubic feet per second per square mile (csm) to account for the difference in watershed area

**TABLE 2-7
FEMA Estimated Peak Flows at Hale Eddy Gauge**

Recurrence Interval (years)	1979 Flood Insurance Study (cubic feet per second)	2010 Flood Insurance Study (cubic feet per second)	% Change
500	20,500	58,900	+187
100	16,300	37,180	+128
50	14,705	29,940	+104
10	11,300	16,840	+49

Peak flood flow rates along the WBDR developed for the most recent FIS were employed for one-dimensional modeling of the main stem of the river. These were developed from statistical analyses of the stream gauges at Stilesville and Hale Eddy and implement drainage area weighting and scaling techniques described in USGS Scientific Investigations Report (SIR) 2006-5112. These flows were used with the accompanying hydraulic model because they are the current regulatory standard for the majority of the studied area and were derived from a recent and comprehensive hydrologic study. Note that these are the flows used in the effective FIS for Delaware County but the preliminary FIS for Broome County, including the village of Deposit and town of Sanford.

The web-based tool, "Application of Flood Regressions and Climate Change Scenarios to Explore Estimates of Future Peak Flows," developed by the USGS (Burns et al., 2015a,b) was used to obtain estimates for changes in peak flood flows under a range of projected climate change scenarios at different periods in the future. This tool is currently only available for New York State and was used to assess flooding conditions that may occur in future decades, enabling proactive flood mitigation measures. These may include restricting development in areas that are not currently regulated floodplains but are reasonably expected to be in the future based on climate change projections or identifying bridges that currently perform well but may become hydraulically inadequate in the future.

Precipitation data were evaluated for two future scenarios, termed "Representative Concentration Pathways" (RCP), that provide estimates of the extent to which greenhouse gas concentrations in the atmosphere are likely to change through the 21st century. RCP refers to potential future emissions trajectories of greenhouse gases such as carbon dioxide. RCP 4.5 is considered a midrange emissions scenario, and RCP 8.5 is a high emissions scenario. Resulting precipitation and runoff estimates are based on five different climate models and are input into the USGS *StreamStats* program, a web-based implementation of regional hydrologic regressions. Percent increases over *StreamStats* regression estimates based on current climatic data, as computed for the watershed just upstream of the confluence with the EBDR, were applied to corresponding design flood flows in the FEMA hydraulic model downstream of the Cannonsville Reservoir in the WBDR model. Mean estimated increases based on the five climate models are presented in Table 2-8. These are based on regressions for Flood Frequency Region 4 in New York.

TABLE 2-8
Predicted Increases in Flows on the WBDR
(Based on two climate change scenarios for three periods in the future as measured just upstream of the confluence with the EBDR. Highlighted increases in the 100-year flood were assessed with hydraulic modeling described in Section 2.4.)

Flood Event (years)	RCP 4.5 (% Increase)			RCP 8.5 (% Increase)		
	2025-2049	2050-2074	2075-2099	2025-2049	2050-2074	2075-2099
500*	10	12	12	12	13	18
200	10	13	13	12	13	19
100*	11	14	13	13	14	20
50*	11	14	14	13	15	21
25	12	15	14	14	15	22
10*	13	16	16	15	17	24
5	14	18	17	17	18	26
2	16	20	20	19	21	31

* FEMA flow profile

Projected future flows for the 50- and 100-year flood events were modeled as these are important design flows for bridges. More significant changes are projected for more frequent flow events, which are generally more appropriate for use in smaller culvert design; replacement structures on the WBDR and its tributaries should consider the future flow scenarios that are appropriate for the required design flows and anticipated structure lifespan. Hydraulic profiles of both existing conditions and projected future flow increases at bridges in High Risk Areas along the WBDR are plotted in their respective sections. Changes in peak flood flows on the order of 10% to 20% are sufficient to overwhelm bridges that are currently adequate, and dramatic increases in backwater flooding are possible. It is recommended that all future bridge replacements along the WBDR be accompanied by a new hydrologic analysis of the river's gauges and that conservative future flow increases be applied as well.

2.4 Hydraulics

In order to assess flooding and mitigation alternatives, the most recent FEMA HEC-RAS hydraulic models were obtained for areas of the WBDR watershed where they were available, which was limited to the WBDR itself. Modeling was obtained from the NYSDEC, Floodplain Management Section, Bureau of Flood Protection and Dam Safety, which is gratefully acknowledged.

Hydraulic analyses on the WBDR were conducted using the HEC-RAS computer software. This program was developed by the United States Army Corps of Engineers (USACE) Hydrologic Engineering Center and is the industry standard for riverine flood analysis. The model is used to compute water surface profiles for one- and two-dimensional, steady- and unsteady-state flow conditions. The system can accommodate a full network of channels, a dendritic system, or a single river reach. Recent advancements in computer processing power have enabled practical application of two-dimensional hydraulic modeling in a growing range of situations. HEC-RAS is capable of modeling water surface profiles under subcritical, supercritical, and mixed-flow conditions. Water surface profiles are computed from one cross section to the next by solving the

one-dimensional energy equation with an iterative procedure called the standard step method. Energy losses are evaluated by friction (Manning's Equation) and the contraction/expansion of flow through the channel. The momentum equation is used in situations where the water surface profile is rapidly varied such as hydraulic jumps, mixed-flow regime calculations, hydraulics of dams and bridges, and evaluating profiles at a river confluence. Two-dimensional modeling employs the St. Venant shallow water approximations of the Navier-Stokes equations as numerically discretized by HEC.

One-dimensional hydraulic modeling of the WBDR completed in 2009 under contract for FEMA was employed in flooding and sediment transport analyses along the tailwater reach of the WBDR. This HEC-RAS model was used to determine BFEs and inundation extents in FEMA's effective floodplain mapping of the WBDR in Delaware County as well as the preliminary mapping that has not yet been adopted by Broome County.

Based on the future flows analysis described above, predicted changes to BFE include increases of as much as 1.2 feet in the RCP 4.5 percent scenario for 2025-2049 and up to 6 feet or more in the RCP 8.5 percent scenario for 2075-2099. These were chosen to bracket the range of potential scenarios and coincide with predicted increases in 100-year flood discharge of 11 percent and 20 percent, respectively (see Table 2-7). The village of Deposit and hamlets of Hale Eddy and Stilesville would be significantly affected, along with other homes and communities on both the New York and Pennsylvania banks of the river. An 11 percent increase in 100-year flood discharge generally results in approximately 1 additional foot of flooding depth along the tailwater reaches of the WBDR. The scenario involving a 20 percent increase in the 100-year flood flow results in inundation depths increasing by over 3 feet in some areas of Stilesville, by over 6 feet in parts of Deposit, and over 5 feet in Hale Eddy. Note that for Broome County these increases are compared to the preliminary FEMA flood profiles; when measured against the archaic effective mapping for the village of Deposit and town of Sanford, increases are up to between 13 and 15 feet.

Projected future increases in flood flows on the WBDR are expected to have considerable consequences in terms of flooding damages and should be considered in long-term community planning, including home relocations or proposed new developments. Increases in peak flood discharges are also predicted to significantly affect the hydraulics of some bridges; new or replacement crossings are likely to have design lifetimes extending well into the 2075-2099 time frame, so consideration of future flows is critical when sizing these structures.

2.5 Planning Documents

Village and Town of Hancock Tourism Plan (SUNY ESF, 2007)

While the plan is dated at this point, issues and opportunities identified in the document may still be relevant. Therefore, we have summarized the highlights related to flooding. The plan noted that many of the tourists to the region are there for opportunities to recreate on the Delaware River, particularly for fishing. Access limitations to the river were noted as a concern, and the lack of boating in particular was found to be an issue that was recommended to be addressed through a balance of improving access while at the same time protecting the river. Flooding was noted as a seasonal concern related to transportation, roads, and scenic byways and the issues it can

present to accessibility and safety as well as the damage it does to roads, homes, and infrastructure. Hancock was noted as having the potential to become a hub for recreation in the area. There are several recommendations related to redevelopment and land use design that may be useful for consideration in other elements of this study, including developing a wildlife viewing platform overlooking the river, creating a river walk in the village, improving river access, expanding river rescue abilities, and creating scenic byway pull-off areas.

Village of Hancock Economic and Community Development Plan (Planit Main Street, 2008)

The plan includes a Vision Statement that does not specifically reference flooding but does discuss providing "...sustainable public infrastructure...to meet growing community needs in a cost-effective manner." The study found that many of the vacant parcels in the village were either within the floodplain or contained wetlands or steep slopes. Any development on infill sites was recommended to complement the design aesthetic of adjacent properties, with streets being interconnected where feasible.

Town of Hancock Design Standards (2012)

The design standards adopted by the town were incorporated into the town's Site Plan Review Law. The regulations cover elements such as site design and general compatibility of proposed site development elements; vehicular circulation and access; parking and loading; stormwater and drainage; water and sewer proposals; landscaping; fire-related safety provisions; surface water impact; impact on the neighborhood; and impacts on agriculture, forestry, and mining.

Village of Hancock Zoning Code

The Village Zoning Code includes two residential districts, two business districts, an industrial district, and a Flood Hazard District (OF). The OF District is an overlay that uses the FEMA Zone A flood zone as the boundary. Its purpose is to designate areas where construction controls may be imposed because of varying degrees of flooding potential. The district requires development in this area to be consistent with the U.S. Flood Disaster Protection Act in addition to the underlying zoning district regulations. The Zoning Code includes Special Permit requirements for several uses, including group homes, retirement homes, churches and cemeteries, multifamily conversions, campgrounds, mobile home parks, drive-in facilities, hotels and motels, junkyards, motor vehicle repair shops and retail gasoline outlets, and bed-and-breakfast establishments. All districts also have yard and lot design criteria, including criteria for waterfront lots. Any waterfront lot is required to be located no less than 100 feet from the high-water line of the abutting waterbody.

HMP Jurisdictional Annex for the Village of Hancock

The Jurisdictional Annex document provides details related to hazard vulnerabilities in the village, a history of damage events, and significant related information on hazards. The HAZUS-MH estimates in the document showed that for a 1 percent annual chance event 289 people may be displaced, and 213 may seek short-term shelter. This represents nearly 16 percent and just under 12 percent of the town's population, respectively. For the 0.2 percent annual chance event, the document estimated that 428 people (just over 19 percent) may be displaced, and 94 people (just

over 4 percent) may seek short-term shelter. In total, there was just over \$21M of total assessed property exposed to the 1 percent annual chance event and over \$22M for the 0.2 percent chance event. The Annex lists future needs to better understand risk/vulnerability. This effort would require significant fieldwork to identify details related to each property that has been identified as being vulnerable to flooding.

HMP Jurisdictional Annex for the Town of Deposit

The Jurisdictional Annex document provides details related to hazard vulnerabilities in the town of Deposit, a history of damage events, and significant related information on hazards. The HAZUS-MH estimates in the document showed that for a 1 percent annual chance event 106 people may be displaced, and 45 may seek short-term shelter. This represents just over 13 percent and 5 percent of the town's population, respectively. For the 0.2 percent annual chance event, the document estimated that 110 people (nearly 14 percent) may be displaced, and 48 people (6 percent) may seek short-term shelter. In total, there was approximately \$7.5M of total assessed property exposed to the 1 percent annual chance event and over \$7.5M for the 0.2 percent chance event. The Annex lists future needs to better understand risk/vulnerability. This effort would require significant fieldwork to identify details related to each property that has been identified as being vulnerable to flooding.

Village of Deposit Comprehensive Plan (2017)

The Comprehensive Plan begins with an immediate reference to the devastating flood of June 28, 2006. This flood had a major impact on the community, including a decline in manufacturing after the flood. Combined with competition for retail from retail centers in the southern tier, the village has been hit hard since the early 2000s. The flood severely impacted businesses within the industrial park along Airport Road. Additionally, the report notes that revised FEMA FIRMs have greatly limited the redevelopment potential in this area.

One of the objectives of the Comprehensive Plan is to preserve prime farmlands along Laurel Bank Avenue that, among other things, provide undeveloped land that helps to mitigate effects of periodic flooding on the village. An additional objective encourages the preservation of floodplains (and other natural features) and protection of the groundwater supply, topographic features, and scenic vistas regarding development projects. It calls for best practices for stormwater management and encourages seeking opportunities to purchase conservation easements along the WBDR to create a greenway linking the proposed waterfront park.

The plan notes that a manufactured home park was purchased through a FEMA and NYS State Emergency Management Office voluntary flood buyout program after the 2006 flood. The village secured a grant to create a master plan for the 3.3-acre waterfront site. FEMA identified and mapped flood hazard areas in the village and the downtown business district, and a large percentage of the housing stock is within the floodplain.

Finally, the village's new design guidelines provide standards for developing in the floodplain areas. This plan recommends development of riparian zones along all major streams, including the WBDR, the Oquaga Creek, and Butler Brook as well as their tributaries to help prevent stream bank erosion and to mitigate damage during flood events.

Village of Deposit Zoning Regulations

The village Zoning Code includes eight zoning districts – two commercial and business districts, one industrial district, four residential districts, and one open space district. The code includes use and bulk regulations, parking and loading regulations, site plan approval requirements, special permit requirements, and other regulations related to administration and enforcement.

HMP Jurisdictional Annex for the Village of Deposit

The Jurisdictional Annex document provides details related to hazard vulnerabilities in the village, a history of damage events, and significant related information on hazards. The HAZUS-MH estimates in the document showed that for a 1 percent annual chance event 587 people may be displaced, and 417 may seek short-term shelter. This represents just over 30 percent and 21 percent of the village's population, respectively. For the 0.2 percent annual chance event, the document estimated that 647 people (just over 33 percent) may be displaced, and 465 people (24 percent) may seek short-term shelter. In total, there was approximately \$1.5M of total assessed property exposed to the 1 percent annual chance event and over \$1.5M for the 0.2 percent chance event. The Annex lists future needs to better understand risk/vulnerability. This effort would require significant fieldwork to identify details related to each property that has been identified as being vulnerable to flooding.

Delaware County Multi-Jurisdictional Hazard Mitigation Plan

The purpose of Hazard Mitigation Plans (HMP) is to identify policies and actions that will reduce risk in order to limit losses of property and life. Flood hazard mitigation, in particular, seeks to implement long- and short-term strategies that will successfully limit loss of life, personal injury, and property damage that can occur due to flooding (URS, 2009). Flood mitigation strategies are most successful when private property owners; businesses; and local, state, and federal governments work together to identify hazards and develop strategies for mitigation (Tetra Tech, 2009).

The benefits of HMPs include but are not limited to the following:

- An increased understanding of hazards faced by communities
- A more sustainable and disaster-resistant community
- Financial savings through partnerships that support planning and mitigation efforts
- Focused use of limited resources on hazards that have the biggest impact on the community
- Reduced long-term impacts and damages to human health and structures and reduced repair cost (Tetra Tech, 2013)

Flood hazard mitigation planning is promoted by various state and federal programs. At the federal level, FEMA administers two programs that provide reduced flood insurance costs for communities meeting minimum requirements: the NFIP and the Community Rating System (CRS) (Tetra Tech, 2013). Flood hazard planning is a necessary step in acquiring eligibility to participate in these programs (URS, 2009).

In 2013, Delaware County completed a multijurisdictional natural HMP. By participating in the plan, jurisdictions within the county comply with the Federal Disaster Mitigation Act of 2000. Compliance with this act allows jurisdictions to apply for federal aid for technical assistance and postdisaster mitigation project funding.

Hazards were ranked based on probability of occurrence and impact on the community. Delaware County was assigned an occurrence ranking of 'frequent' or '3' for flooding, indicating a hazard event that is likely to occur within 25 years. The impact ranking is determined based on the impact on population, impact on property (general buildings and critical facilities), and impact on the economy. A ranking of high, medium, or low is assigned to each of these factors based on historical losses and subjective assessment and is then used to calculate the overall ranking. Flooding in Delaware County was assigned a ranking of 'medium.' As a result, the overall hazard ranking for flooding in Delaware County is 'high.'

According to the HMP, as of 2012, FEMA has identified 27 NFIP policies for the town of Deposit, with 19 policies located in the 1% annual chance flood boundary, 20 policies in the 0.2% annual chance flood boundary, and 7 policies located outside the 0.2% annual chance flood boundary. The town of Colchester has three Repetitive Loss properties and one Severe Repetitive Loss property. Within the village of Deposit, 115 properties, representing 767 residents, and 127 properties, representing 853 residents, lie within the 1% and 0.2% annual chance flood boundaries, respectively. NFIP data were not available for the village or Broome County. In the town of Hancock, FEMA has identified 121 NFIP policies, with 24 policies located in the 1% annual chance flood boundary, 31 policies in the 0.2% annual chance flood boundary, and 90 policies located outside the 0.2% annual chance flood boundary. The town of Hancock has 12 Repetitive Loss properties and two Severe Repetitive Loss properties.

2.6 Stakeholder Meetings

An important component of the data gathering for this study took place through stakeholder engagement. Three formal stakeholder meetings were convened by video conference call. The first meeting was held on the morning of May 15, 2020, and included participation from NYSDEC, OGS, Delaware County Soil and Water Conservation District (DCSWCD), and Friends of Upper Delaware River (FUDR). The second meeting was held on the evening of June 18, 2020, with participation from members of the Upper Delaware River Tailwaters Coalition (UDRTC), to share the results of the analysis and review initial findings and recommendations. On December 17, 2020, a second meeting was held with UDRTC to share final recommendations and gather feedback. In addition to the formal video conferences, many one-on-one conversations took place with representatives from WBDR watershed municipalities, FUDR, DCSWCD, NYCDEP, and NYSDEC.

3.0 IDENTIFICATION OF FLOOD HAZARDS

3.1 Overview of Flooding Sources

Communities along the WBDR are generally situated at the river's confluence with smaller tributaries, where sediment deposition has produced relatively flat, well-drained land that is amenable to development and agriculture. These areas experienced substantial growth associated with the burgeoning agriculture, bluestone quarrying, and timber and derivative product industries in the 19th and early 20th centuries. Flooding in these communities can come from these tributaries, the WBDR, or both. The extents of tributary flooding near the confluence can be highly dependent on the presence or absence of tailwater controls from the WBDR. Depending on antecedent conditions, as well as a community's distance downstream from the Cannonsville Reservoir, the dam may offer effective, albeit unpredictable, flood control services.

Several communities lie atop active depositional features such as alluvial fans and outwash deltas where aggradation is constant, and natural channel migration is frequent. The surficial geology of the WBDR's tributary watersheds is comprised primarily of glacial drift, including till. This material can have vastly different characteristics depending on its specific depositional setting within the glacial environment, but much of the material that comprises these heterogenous amalgamations of materials, ranging from clays to boulders, can be transported by these steep tributaries over much of their lengths. However, while the smaller sands, silts, and clays are carried on downstream, these streams lose competence to transport the larger particles – gravels, cobbles, and boulders – once they reach the relatively flat valley floor. Because these larger stones are not readily transported by the WBDR either, over time, deposited sediments accumulate into alluvial fans, which are highly dynamic environments. Flooding in adjacent developed areas can be especially damaging.

Historical straightening, dredging, and berming of the tributaries to the WBDR have fostered incision and entrenchment of these streams. Confined flood flows can produce damaging erosive forces that attack the vulnerable, overly steep banks of the incised channels, frequently damaging or destroying adjacent roadways and property and causing bank failures that can release enormous volumes of sediment into the stream. As a result, avulsions occur as channels are filled with sediment and debris, and streams find new, and damaging, flow paths. Tributary flooding frequently occurs during highly localized flash flooding events that hardly register on the WBDR itself. Bridge and culvert openings clog and jam with sediment, wood, debris, or ice, and property is lost as the stream shifts its banks or flanks around bridges. Considerable time, effort, and money are expended in efforts to reclaim property and retame the stream, only to have the same issues develop during the very next flood. This has resulted in unstable and impaired reaches along these tributary streams, with infrastructure and property at considerable risk.

The roads that parallel the WBDR are critical routes in flood emergencies as are those that follow the tributaries up their respective valleys. Many of the latter are maintained by local municipalities with limited budgets for infrastructure, but these are often the only available detours to and from small communities when the WBDR has flooded or damaged the main roads in the valley. Emergency services are limited to the larger hamlets and villages; several communities along the WBDR must rely on external assistance and are vulnerable to being cut off due to minimal redundancy in this rural region's road networks.

3.2 Flooding History

The Catskill Mountains are subject to large storm events that are often unevenly distributed across watersheds. As a result, local flash floods can occur in one basin while adjacent areas receive little or even no rainfall. In addition to localized events, larger storms can cause widespread flooding. An examination of stream flow gauge records indicates that flood events can take place any time of the year but are generally bimodally distributed, divided into those occurring in winter and spring and those occurring in summer and fall. Floods in winter and spring are associated with rain-on-snow events and spring snowmelt while those that take place in the summer and fall are typically brought on by extreme rainfall events that are frequently associated with hurricanes and tropical storms.

According to the National Oceanic and Atmospheric Administration's (NOAA) National Climatic Data Center storm events database, 106 flood or flash flood events have been reported in Delaware County between 1996 and 2019, with 171 events in Broome County over the same time period. Between the two counties, these floods resulted in a combined 22 deaths and over \$1.175 billion in reported damages to property and crops although actual losses are likely considerably greater due to underreporting, lost revenues, and other intangibles. Several of the major floods that have occurred during the past century are summarized in Table 3-1 below; emphasis is placed on the more recent events for which more data are available, and this is by no means an exhaustive list. Some of these floods were experienced on tributaries in the watershed or in the WBDR watershed above the Cannonsville Reservoir while the tailwater section of the WBDR did not flood proportionately. This may occur either because they were flashier flood events that were attenuated by the natural hydrological processes of the watershed or because the Cannonsville Reservoir had sufficient void to absorb the flood wave that developed upstream. Major flood events on the main stem may have occurred due to more prolonged or severe precipitation (or equivalent precipitation in the case of snowmelt events), because the reservoir was already at or near capacity when floodwaters from upstream hit, or both. Coincident flooding of the tributaries and main stem is also possible.

Figure 3-1 is a hydrograph showing annual peak flows recorded at the Hale Eddy USGS gauge (01426500). Flood recurrence information from FEMA showing the magnitude of the 10-, 50-, and 100-year flood events has been superimposed on the hydrograph. There is a marked reduction in the magnitude of peak flows beginning in 1963 due to the attenuating effect of the Cannonsville Reservoir. This influence is reduced along with downstream distance from the reservoir as unregulated tributaries join the WBDR.

TABLE 3-1
Selected WBDR Flood History
(Approximate return intervals are compared to effective FEMA flows
at the listed location. Damage valuations as reported in Delaware County
Multi-Jurisdictional Hazard Mitigation Plan [Tetra Tech, 2013].)

Date	Discharge (cubic feet per second) and location	Notes
October 1903	Approximately 46,000 at Hale Eddy (between Q100 and Q500)	"Pumpkin Flood" 5" to 10" of rain Historic peak at Hale Eddy (pre-gauge)
September 1938	25,600 at Hale Eddy (<Q50)	"The Great New England Hurricane"
March 1948	28,900 at Hale Eddy (Q50)	
August 1955	13,300 at Stilesville (<Q10) 16,000 at Hale Eddy (Q10)	"\$1 Billion Hurricane" (1955 dollars) Back-to-back Hurricanes Connie and Diane, less than a week apart
January 1996	13,200 at Hale Eddy (<Q10)	Severe snowmelt event occurred when temperatures hit about 60 degrees and 3" or more of rain fell on 5"+ of liquid equivalent in snowpack. Ice jams contributed to flooding. Severe tributary flash flooding occurred.
September 2004	17,500 at Hale Eddy (Q10)	Remnants of Hurricane Ivan \$747K expenses or losses reported in Colchester
April 2005	14,800 at Stilesville 21,500 at Hale Eddy (>Q10)	High pre-storm flows; 3" to 6" of rain plus snowmelt Over \$3.2M in damages reported in Colchester \$1.6M in damages reported in Hancock Two fatalities in village of Deposit Second only to 2006 flood at Stilesville gauge
June 2006	33,100 at Stilesville (Q100) 43,400 at Hale Eddy (between Q100 and Q500)	Up to 12" of rainfall Over \$10.1M damages reported in town of Colchester \$11.1M damages reported in Hancock \$1.8M in repairs reported in village of Deposit Flood of record at Stilesville gauge; second to 1903 flood at Hale Eddy Flood of record on Oquaga Creek at Deposit
June 2007		Extreme tributary flash flooding Up to 10"+ of rain in ~3 hours Damage to Routes 207/7 Town of Colchester over \$7.5M damages
October 2010		Remnants of Tropical Storm Nicole 3" to 9" of rain Absorbed by Cannonsville Reservoir; was Q10 on WBDR upstream at Walton
August-Sept 2011	22,200 at Hale Eddy (between Q10 and Q50)	Back-to-back tropical storms Irene (up to 18" of rain) and Lee (2" to 9") about a week apart Irene flood wave absorbed by Cannonsville Reservoir; spilled in Lee

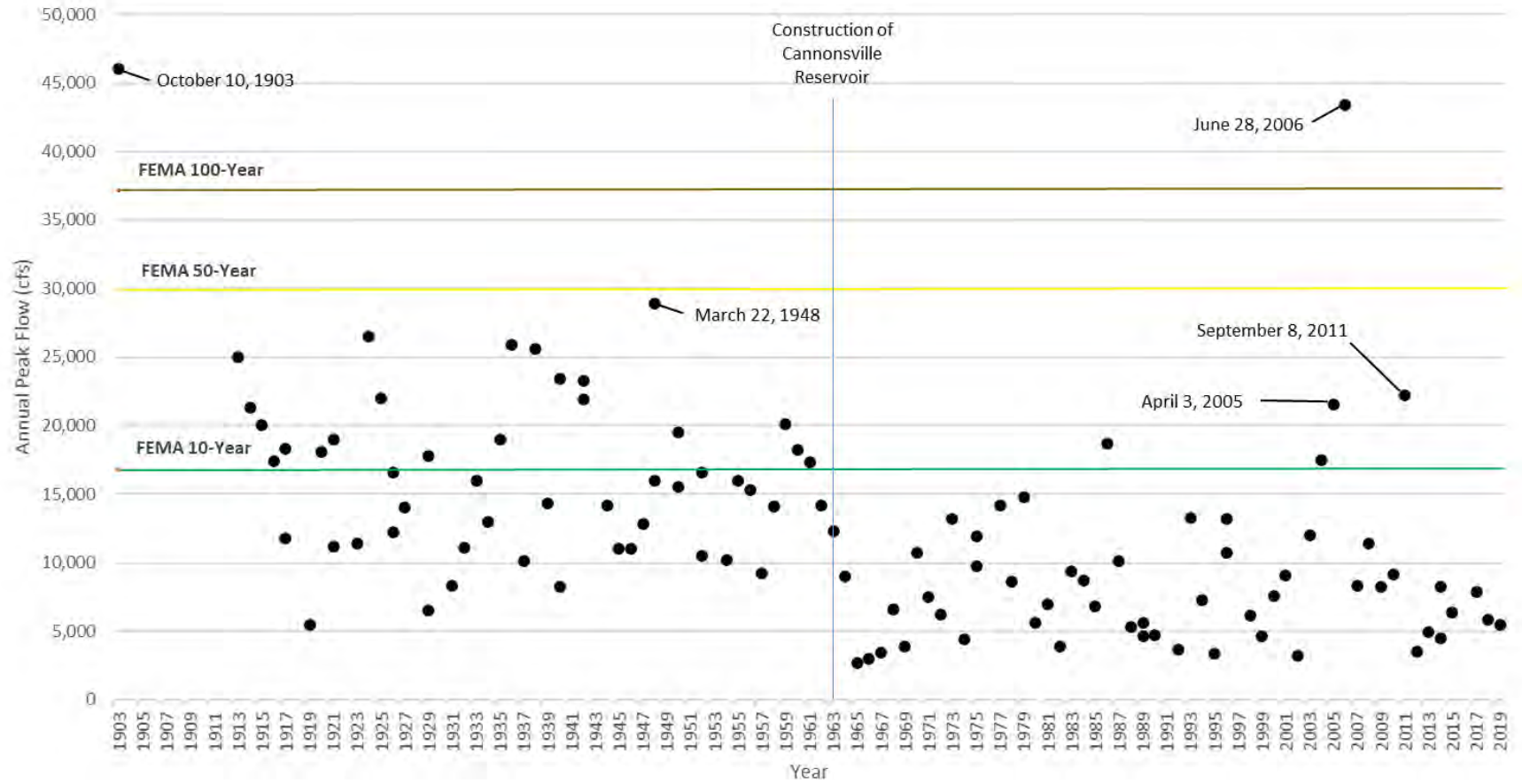


Figure 3-1
Hydrograph of Annual Peak Flow on the WBDR at Hale Eddy
1903 - 2019

3.3 FEMA Mapping

As part of the NFIP, FEMA produces FIRMs that demarcate the regulatory floodplain boundaries. As part of a FIS, the extents of the 100-year and 500-year floods are computed or estimated as well as the regulatory floodway if one is established. The area inundated during the 100-year flood event is also known as the SFHA. In addition to establishing flood insurance rates for the NFIP, the SFHA and other regulatory flood zones are used to enforce local flood damage prevention codes related to development in floodplains.

Over the period of a standard 30-year property mortgage, a property located within the SFHA will have a 26 percent chance of experiencing a 100-year flood event. Structures falling within the SFHA may be at an even greater risk of flooding because if a house is low enough it may be subject to flooding during the 25-year or 10-year flood events. During the period of a 30-year mortgage, the chance of being hit by a 25-year flood event is 71 percent, and the chance of being hit by a 10-year flood event is 96 percent, which is a near certainty.

The FIS for Delaware County (36025CV001B) has been effective as of 2012, with revisions in effect as of 2016. FIRM panels for the WBDR in Delaware County, including the towns of Hancock and Deposit (excluding the village of Deposit), were produced based on hydraulic modeling completed in 2009 and made effective in 2012, with revisions as of 2016. For Broome County, the WBDR floodplain was mapped as part of the same hydraulic modeling effort. Preliminary FIRM panels and a FIS report were produced in 2010 (36007CV001A) but have yet to be adopted by the Town of Sanford or Village of Deposit. Until and unless it is, the effective FIS and FIRM panels for the WBDR in these jurisdictions will continue to be those that were produced in the late 1970s and reflect both the hydrologic and hydraulic conditions and the modeling capabilities of that time. Effective flood mapping for the village of Deposit is from 1979 based on a FIS dated August 1978 (360043V000); the FIS for Sanford (360054V000) dates to 1979, with FIRM panels produced in 1980.

BFEs that have been determined by the more recent modeling are between 5 and 9 feet higher than what was computed in these older studies. As a result, the effective regulatory floodplain mapping in these areas does not accurately represent the flood hazard as it is understood today; many residents on the Broome County side of the WBDR valley are likely to be uninsured or underinsured through the NFIP, and restrictions on floodplain development are likely inadequate. Residents may be unknowingly or unnecessarily at risk, and while flood insurance studies are by no means infallible, it is certainly conceivable for property damage, personal injury, or loss of life to occur as a direct or indirect consequence of a jurisdiction's failure to adopt the most modern FIS available.

3.4 Cannonsville Dam

The NYSDEC assigns a hazard classification to dams based on the expected consequences of a dam failure. The Cannonsville Dam is categorized as a Class C "high-hazard" dam. This classification indicates that "a dam failure may result in widespread or serious damage to home(s); damage to main highways, industrial or commercial buildings, railroads, and/or important utilities, including water supply, sewage treatment, fuel, power, cable or telephone infrastructure; or substantial environmental damage; such that the loss of human life or widespread substantial economic loss is likely" (NYSDEC DOW-TOGS 3.1.5). Note that this has no bearing on the dam's probability of failure but considers only the hazard that may manifest if it does.

4.0 FLOOD MITIGATION ANALYSIS

In this section, flood-prone communities along the WBDR are identified, and an analysis of flood mitigation considerations within each flood-prone community is undertaken. Factors with the potential to influence more than one WBDR community are also evaluated and discussed. These include the effect of the Cannonsville Reservoir on downstream peak flows and the behavior of sediment as it is transported along the WBDR channel. These overarching factors are discussed first, followed by discussion of each flood-prone community.

High Risk Areas in communities along the WBDR were assessed for flooding hazards and potential mitigation strategies. Flood-prone areas, critical facilities, bridge constrictions, historical damages, and emergency access and detour availability were considered in these analyses. Isolated homes and a few small communities in Pennsylvania situated along the WBDR were not assessed. Figure 4-1 presents an overview of flood-prone communities that were evaluated.

Specific flood mitigation alternatives detailed for individual areas are outlined where applicable. Unfortunately, the lack of modern hydrologic analyses and hydraulic modeling on tributary streams precludes in-depth alternatives analysis for high-risk areas prone to flooding from these sources. Several alternatives for these areas are presented in the Delaware County Multi-Jurisdictional Hazard Mitigation Plan. While these strategies seem appropriate, Milone & MacBroom, Inc. (MMI) did not perform additional analyses, which would require development of detailed hydraulic modeling. General recommendations are presented in Section 5. These include infrastructure improvements like bridge and culvert replacements, road relocations, stream restoration and floodplain reconnection, establishment of riparian buffers, individual property protection measures, and relocations of homes and businesses. Where hydraulic modeling of tributary stream is antiquated, it is recommended that communities in high-risk areas seek updated analyses to inform development of holistic flood mitigation strategies.

Following the identification map and matrix of each High Risk Area is a high-level conceptual relocation "Master Plan" of potential relocation areas. This is simply an exercise in identifying potential areas where relocation generally seems to make sense for residential, retail/commercial, industrial, and other land uses identified as flooded through this assessment. It in no way suggests these are the only locations or that they are adequate to relocate all properties identified as being within the floodplain. There are many caveats to the exercise, and any relocation efforts will require significant coordination between landowners eligible for relocation, landowners interested in selling land for new development, local government input, and requirements and regulations by funding and assistance agencies from the state to federal levels.

4.1 Cannonsville Reservoir Influence on Flood Flows

Flooding on the WBDR may or may not coincide with void space in the Cannonsville Reservoir; for a given event, the flood peak attenuation provided by the dam is neither predictable nor reliable. However, long-term trends in peak flow statistics may be indicative of the degree to which the reservoir has impacted the flood hydrology of the WBDR. USGS Bulletin 17B analyses were performed on the annual peak flow data recorded at the Hale Eddy USGS gauge on the WBDR (01426500) for the years before (1903, 1913-1963) and after (1963-2019) construction of the

Cannonsville Dam. Flood recurrence intervals based on these two data sets are presented in Table 4-1.

TABLE 4-1
Peak Flows at Hale Eddy before and after Construction of Cannonsville Reservoir

Flood Event (years)	Peak Discharge (cubic feet per second)		Change (percent)
	Pre-Dam (1903, 1913-1963)	Post-Dam (1963-2019)	
500	45,400	54,700	+20
200	40,800	42,400	+4
100	37,300	34,700	-7
50	33,800	28,000	-17
25	30,200	22,300	-26
10	25,400	16,000	-37
5	21,500	11,900	-45
2	15,500	7,200	-53

Despite the fact that the Cannonsville Dam creates a water supply reservoir, it is capable of providing significant flood control services although it is critical to be clear that the degree to which a flood's peak discharge will be attenuated is highly dependent on reservoir stage at the inception of the flood as well as the magnitude and duration of the event. The outlet configuration of this dam limits releases to 1,840 cubic feet per second (cfs) (with no spilling); at this rate, even with the best forecasting the reservoir cannot be drawn down meaningfully in anticipation of a flood event. However, managing the void is possible at seasonal timescales such as accounting for snowpack over the duration of a winter.

The intricacies of individual events notwithstanding, analysis of peak flows before and after construction of the dam reveals what might be considered the "average" reductions in flood magnitudes that have resulted. Note that no attempt has been made to reconcile these data with length or quality of the gauge record, changes in land use, variable climatic conditions, or other complicating factors that undoubtedly exist, as discussed in Section 2.3.

Analysis of the gauge records at Stilesville and Hale Eddy on the WBDR and the relatively short gauge records on the Delaware River at Lordville and Callicoon indicate that the influence of the Cannonsville Reservoir, while it does diminish somewhat with downstream distance, remains a dominant influence on WBDR hydrology through its tailwater reaches. Mean daily flows on the WBDR at Walton, upstream of the dam, are routinely greater than those measured at either Stilesville or Hale Eddy. Beyond the confluence with the EBDR to form the Delaware River, contributions from the unregulated portions of the watershed overwhelm much of the moderating influence of the New York City reservoirs.

The graphics presented in Figures 4-1 and 4-2 were created using data from USGS gauging stations and postflood analyses (USGS SIR 2014–5058, Floods of 2011 in New York, and USGS Open-File Report 2009–1063, Flood of June 26–29, 2006, Mohawk, Delaware, and Susquehanna River Basins, New York). They include hydrographs from USGS gauges located upstream (at Walton) and downstream (at Stilesville) of the Cannonsville Reservoir and demonstrate the dampening of peak flows due to the attenuating effect of the reservoir. Note that these gauged

flood hydrographs are only part of the total; in its analysis, the USGS also accounted for the contributions of the several tributaries that meet the WBDR upstream of the dam but downstream of the Walton gauge, including those that empty directly into the reservoir. Figure 4-1 is from late August and early September 2011 when Tropical Storms Irene and Lee passed through the region. At the onset of high flows resulting from Tropical Storm Irene, the Cannonsville Reservoir was filled to 84.6 percent of its capacity, meaning that the spillway of the dam at the reservoir outlet was not spilling, and there was substantial void space in the reservoir. This substantial void resulted in complete attenuation of the flood wave. When Tropical Storm Lee arrived in the region 10 days later, the Cannonsville Reservoir was at 96.8 percent capacity, and as a result, the attenuating effect of the reservoir on WBDR flows was not as great as it had been during Tropical Storm Irene.

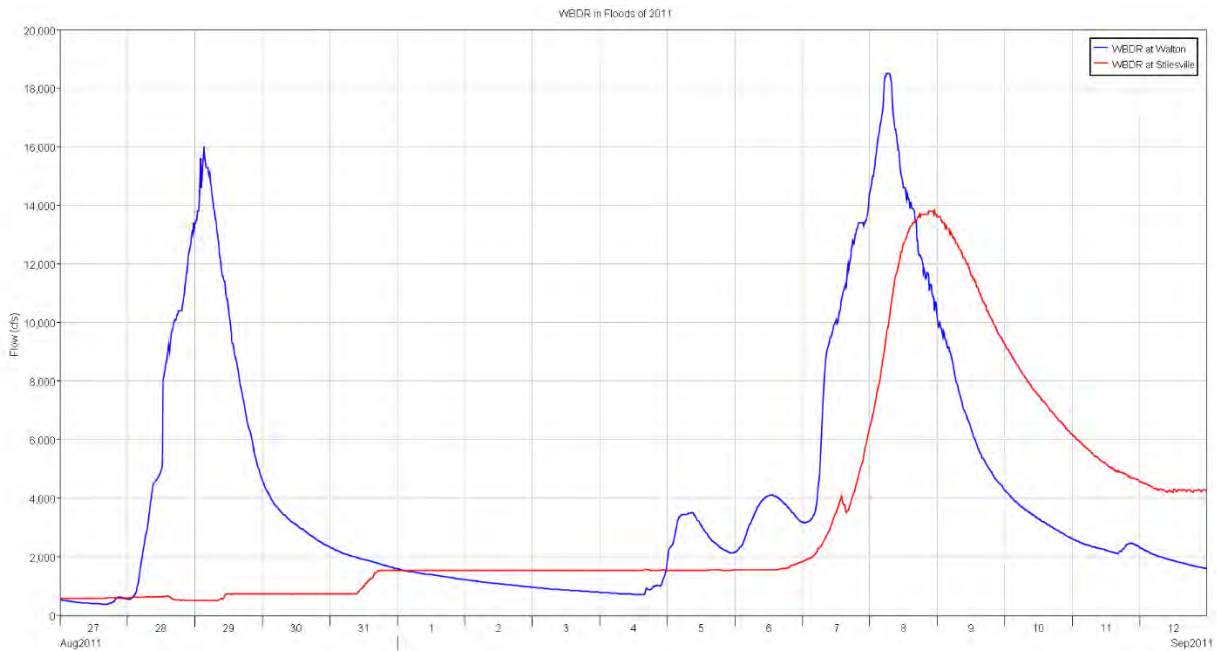


Figure 4-1: Flow Hydrographs for the WBDR at Walton and Stilesville during Tropical Storms Irene and Lee, 2011

At the onset of the June 2006 flood, the Pepacton Reservoir was filled to capacity and spilling, with no void (Figure 4-2). In contrast to the 64 percent attenuation seen during Tropical Storm Irene, the reservoir resulted in a 28 percent attenuation of peak flows during the 2006 flood.

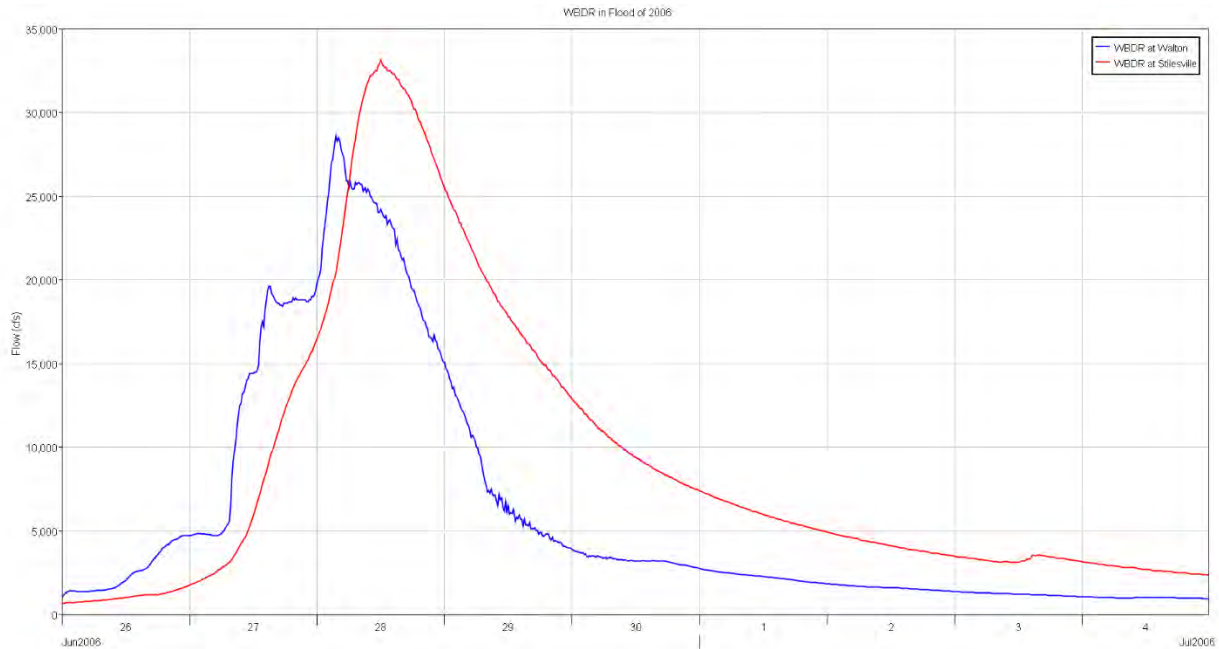


Figure 4-2: Flow Hydrographs for the WBDR at Walton and Stilesville during the 2006 Flood

The Cannonsville Dam often operates with void volume (although it was neither designed for nor operated as a flood control structure) and can completely absorb the flood waves of smaller magnitude, more frequently occurring flood events. During more severe floods, peak flows downstream can also be significantly attenuated even when the dam is spilling. Based on the above analysis, the following can be stated about the influence of the Cannonsville Reservoir on downstream WBDR flood flows:

- The Cannonsville Reservoir substantially attenuates downstream peak flows on the WBDR when it has a void at the start of a flood event.
- The Cannonsville Reservoir moderately attenuates downstream peak flows on the WBDR when it has no void at the start of a flood event.
- The Cannonsville Reservoir does not cause an increase in downstream peak flows during a flood event.
- The attenuating influence of the Cannonsville Reservoir decreases moving downstream as tributaries contribute unregulated flow to the WBDR.

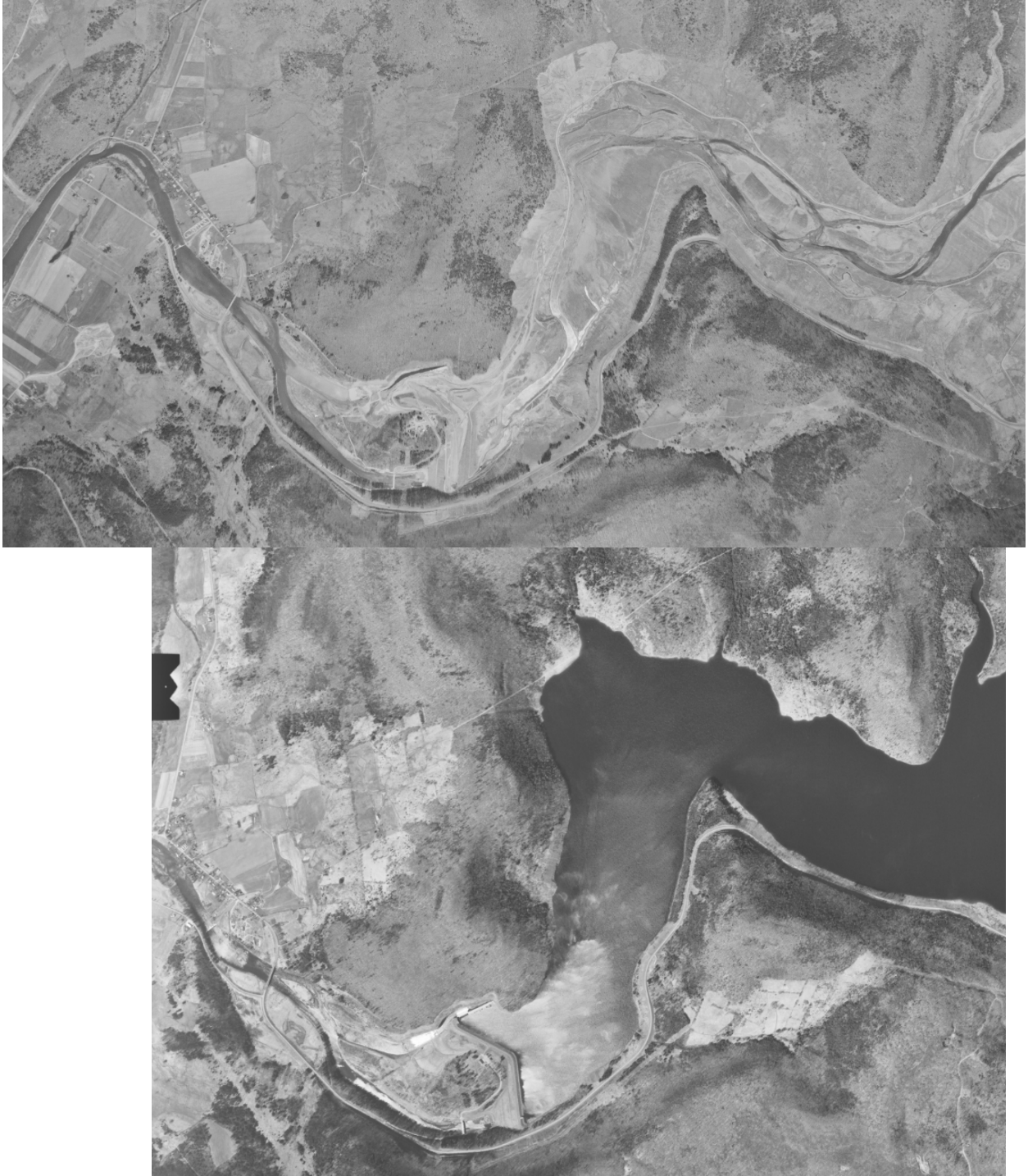


Photo 4-1: Portions of aerial photograph acquired in April 1963 during construction of the Cannonsville Dam (above) and in April 1973 after the reservoir had filled (below). The hamlet of Stilesville is visible on the left side of the images. The bridge over the WBDR in Stilesville has since been relocated approximately 3,500 feet downstream. Retrieved from the USGS Earth Resources Observation and Science Center's *EarthExplorer* online service.

Releases and diversions from the Cannonsville Reservoir are conducted in accordance with the Flexible Flow Management Program (FFMP, commonly known as the "Decree"). This agreement between the members of the Delaware River Basin Commission (DRBC; Delaware, New Jersey, New York, Pennsylvania, and the City of New York) establishes standards and guidelines for withdrawals and minimum flows on the Delaware River, among many other duties. Over 13 million people rely on the Delaware River as a water supply, the majority of whom do not live in New York. Releases from the Cannonsville, Pepacton, and Neversink Reservoirs are prescribed by the Delaware River Master (DRM) to meet combined flow targets set at the confluence of the Delaware and Neversink Rivers in Montague, New Jersey, while total diversions from the Delaware River basin for New York City cannot exceed 800 million gallons/day (1,240 cfs).

The Cannonsville Reservoir can release up to 1,840 cfs when it is not spilling and does so at the direction of the DRM in order to fulfill various objectives in the basin related to drought management, flood mitigation, minimum flow requirements, void management, thermal management for fisheries resources, endangered species protection, and other ecological considerations in addition to maintaining a quality water supply for all users. The Cannonsville Reservoir is operated to achieve goals locally, at the farthest reaches of the watershed, and even outside of it. Releases are managed to meet the needs of dozens of stakeholders, from spill reduction protocols that reduce flooding on the WBDR to management of the location of the salt front on the Delaware River near Wilmington, Delaware. Void management in the Cannonsville Reservoir is conditional upon these and other dynamics on the river.

As its name implies, the FFMP is "Flexible," and operating procedures are continuously updated based on conditions in the watershed, which may include anticipated municipal demands, measured or predicted winter snowpack, and even ecological considerations. Modifications of operations may also occur as part of scientific research projects that are developed to optimize management of the Delaware River's considerable resources for the benefit of all stakeholders. The River Master, a member of the USGS, assesses and reports on the operations along the river in general and as pertains to compliance with the FFMP for each water year. A several-year lag time on this reporting should be expected although these thorough assessments explain and justify the various actions taken by the DRBC and member parties throughout the year. Currently, these can be accessed at: <https://webapps.usgs.gov/odrm/publications/publications>

A consequence of the Cannonsville Reservoir's release management is that the reliable supply of cold water supports a world-class trout fishery in the tailwaters. Fishing and recreational tourism are now cornerstones of the economy in the WBDR tailwater valley, and various advocacy groups have undertaken considerable efforts to promote river restoration and flood recovery practices that benefit the fishery. Unfortunately, this may lead to the perception that the trout are given more consideration than local residents following flood events, which recently have been frequent and devastating. Generally speaking, many of the stream channel characteristics and features that promote quality trout habitat are shared with holistic flood mitigation and bank stabilization strategies; when properly implemented, these can be more effective and require less maintenance than traditional flood control measures such as dredging and berming.

4.2 Sediment Analysis

In addition to moving water, rivers also transport sediment. During a flood event, the large volumes of water moving downstream have the potential to transport large volumes of sediment, ranging in size from fine silt and sand to large boulders. This section looks at the influence of the Cannonsville Reservoir on sediment transport and at the ability of the WBDR channel to mobilize the coarse sediments that are delivered by its steep tributaries.



Photo 4-2: Sediment bar along the WBDR

Sediment flux continuity can be disrupted by the presence of a dam. Tailwater streams often experience degradation of their channels due to a lack of inflowing sediment, which gets impounded in the upstream reservoir. Downstream of dams, deviation from dynamic equilibrium occurs as materials erode from the bed but are not replaced from upstream. This generally leads to a loss of fine sediments and armoring of the channel bed with well-imbricated coarse materials. It also frequently causes channel incision,

bank failures, and long-term scour issues at bridges and other structures. Erosion during flood events can become more severe as the stream's reduced sediment load leaves it with excess energy available to expend, a phenomenon often referred to as "hungry water."

Channel degradation may also have deleterious consequences for aquatic organisms, which can be sensitive to channel sediment gradations for habitat and spawning success. The influx of sediment from the unregulated tributaries to the WBDR counteracts this process to some degree as this material replaces some of what is impounded by the Cannonsville Dam. However, the presence of the dam also affects the frequency, magnitude, and timing of flood events downstream, which may impact the ability of the river to transport what is delivered by its tributaries.

The USGS conducted a bathymetric survey of the Cannonsville Reservoir in 2015 and compared this with the as-built capacity of the impoundment (USGS SIR 2017-5064). Results indicate that approximately 13 million cubic yards of sediment have accumulated behind the dam since its operation began in 1963, or about 2.7 percent of the total original capacity. Sediment is not delivered at a steady rate, but this translates to an average of 685 cubic yards of sediment being transported by the WBDR into the Cannonsville Reservoir every day (over 45 dump trucks).

Wolman pebble counts were performed on the gravel and cobble bars that have aggraded at the confluence of the following tributaries with the WBDR: Cold Spring Creek, Oquaga Creek, Sherman Creek, and Sands Creek. These steep, high-energy tributaries deposit large volumes of coarse-grained sediments when they reach the relatively flat valley bottom at their respective confluences with the main stem of the river. The sediment gradations determined from these

pebble counts were used to assess the mobility of this material under flood conditions on the WBDR.

The majority of the sediments transported to the WBDR are derived from deposits of glacial drift that are ubiquitous throughout the regional surficial geology. Tributaries flow through till, kame, and glacial outwash that was transported and deposited by the powerful glacial processes that shaped the WBDR valley during the Pleistocene and early Holocene eras. The steep tributaries in confined valleys are able to transport a large portion of this readily available substrate due to both the concentration of the stream's turbulent energy to a narrow channel and the relatively large component of gravity that acts on material in these steep channels. Channel incision and bank failures may contribute to sediment load in these tributaries as well. Regardless of its source, once this material reaches the broad, shallow-slope valley of the WBDR, shear forces and stream power are reduced, and while finer particles like silts, sands, and smaller gravels remain mobile, the river is not competent to transport the larger gravel and cobble material at the rate it is delivered.

The WBDR valley was formed by glaciers over thousands of years, but riverine processes now dominate. The system has not yet reached a new equilibrium.

Naturally, this material would fall out soon upon reaching the valley floor and contribute to growth of the alluvial fan. However, channelization of tributary streams maintains some degree of energy concentration, and these coarse sediments are transported farther and end up deposited in population centers or once meeting the WBDR.

The occurrence of this phenomenon is evidenced by the gravel and cobble bars, alluvial fans, and other aggradational features that are ubiquitous at tributary junctions. These depositional features trigger morphological response by the WBDR, generally through lateral migration. As the tributaries deposit material at their confluence with the WBDR that it cannot transport, the river is forced to erode into the opposite bank. Unfortunately in the WBDR valley, this natural process may threaten roadways, homes, or other infrastructure or property. Along much of the river, tributary depositional features have pushed the WBDR to one or the other valley wall, which may be defined by natural terrain, or by the hard-armored embankments of Route 17, or the NYSW Railway, and further lateral migration is restricted.

In some cases, the sediment delivered to the WBDR by its tributaries can be intermittently mobilized by natural, cyclical fluvial processes. Depositional material that fills the WBDR channel behaves as a dynamic grade control, creating a locally reduced stream slope upstream of a tributary junction and an increased slope downstream. Once a threshold gradient is achieved downstream of the inflection, the aggraded sediment can mobilize, and a headcut will propagate upstream through the affected reach to reestablish an equilibrium slope. This process is unpredictable and may occur rapidly during a flood or can happen more slowly as a chronic process.

Much of the WBDR's substrate is nonalluvial in origin, having been delivered to the valley by glacial processes several thousand years ago. Today, these sediments continue to be delivered to the valley floor by tributaries with more unit energy than the WBDR can achieve in the wide, shallow valley it has inherited.

While it was neither designed for nor operated as a flood control structure, the Cannonsville Dam often has void volume and can completely absorb the flood waves of smaller magnitude, more frequently occurring flood events; during more severe floods, peak flows downstream can also be significantly attenuated even when the dam is spilling – for example, the entirety of the Tropical Storm Irene flood wave on the WBDR was absorbed by the reservoir although it did spill

during Tropical Storm Lee about a week later. Disruption of the natural flow regime undoubtedly has an impact on sediment flux in the WBDR downstream of the reservoir as the frequency and duration of high-flow events are reduced. However, the occurrence of floods on the WBDR with sufficient energy to transport the gravel and cobble delivered by the tributaries has not been appreciably affected. This is primarily due to the prodigious discharges required to mobilize these coarse sediments given the broad, shallow river valley geometry of the WBDR.

The competence of the WBDR to transport the sediments derived from its tributaries was quantitatively assessed using the Sediment Transport Capacity (STC) hydraulic design module of the USACE's HEC-RAS software. One-dimensional hydraulic modeling developed by FEMA was used to determine the flow characteristics necessary to assess competence, such as depth, velocity, slope, shear stress, and stream power, over a range of flood flows. Material representing both the median grain size (d50) and 84th percentile grain size (d84) of the sampled bars was assessed; the d50 is generally considered to be the characteristic particle size of the sample, and the d84 is more representative of the material that comprises the armoring layer that develops in gravel and cobble streambeds, which can effectively shield smaller particles from fluvial entrainment.

Results indicate that at the aggradational features at the assessed tributary junctions the WBDR cannot mobilize significant quantities of representative depositional material until flows are in excess of the 10-year to 50-year flood magnitude. It is critical to note that the available hydraulic modeling limits this analysis to average channel hydraulics at the reach scale; local variability in cross-sectional geometry and channel slope are not captured by this model, nor is the nonuniform lateral distribution of shear forces within the channel. Within these reaches, there are locations where flow conditions are capable of mobilizing this coarse material in lesser-magnitude flows although generally only for relatively short distances. Results of the sediment analysis are summarized in Table 4-2 and are shown graphically in Figure 4-4.

**TABLE 4-2
Sediment Size Measurements at WBDR Tributary Confluences**

Tributary Junction	Mean Slope (percent)	d50 (millimeters)	Grain Size	d84 (mm)	Grain Size
Cold Spring Creek	1.8	46	Very Coarse Gravel	100	Medium Cobble
Oquaga Creek	0.7	39	Very Coarse Gravel	60	Small Cobble
Sherman Creek	2.4	60	Small Cobble	126	Medium Cobble
Sands Creek	1.5	61	Small Cobble	111	Medium Cobble

Overall, the coarse material within the aggradational features in the WBDR is relatively stable on decadal timescales, which is the case both upstream and downstream of the Cannonsville Reservoir. Fundamentally, this is because the river's substrate is nonalluvial in origin, having been delivered to the valley by glacial processes several thousand years ago. Today, these sediments continue to be delivered to the valley floor by tributaries with more unit energy than the WBDR can achieve in the wide, shallow valley it has inherited. Analysis of historical aerial imagery and mapping reveals that the river's anabranching planform and many of the depositional features within the channel have been relatively unchanged over the past 70 to 80 years. The growth of new depositional features unrelated to tributary inputs is generally limited to the slack waters downstream of bridge piers.

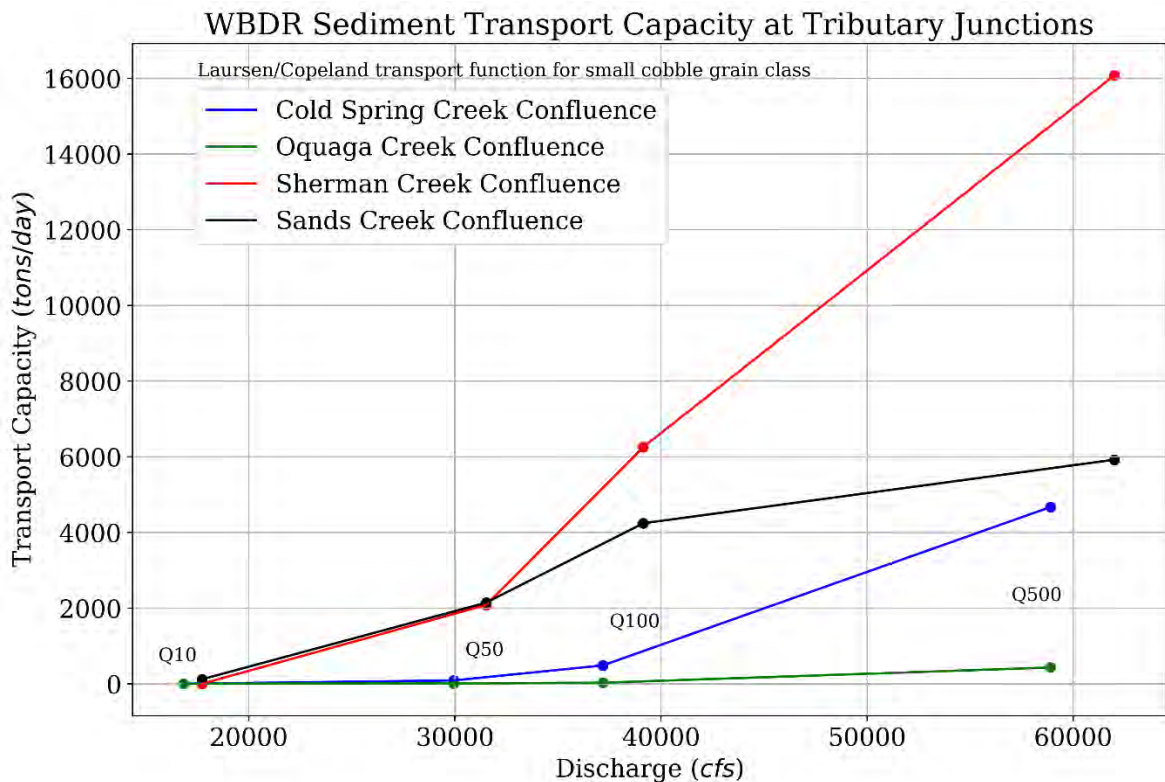
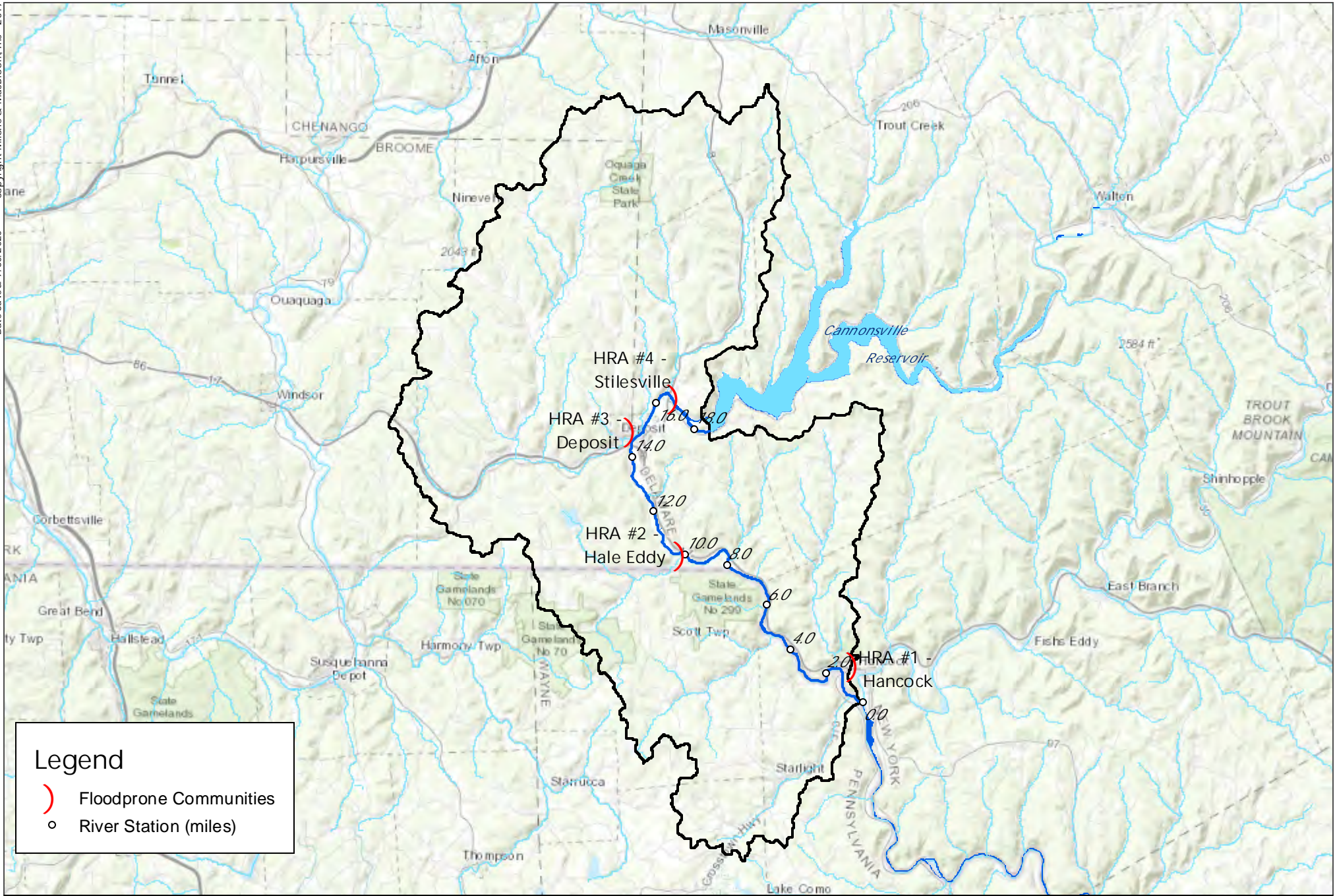


Figure 4-3: Transport capacity of small cobble grain class for the WBDR at representative tributary junctions based on FEMA modeling. Channel and valley characteristics result in some variability in competence in the most severe floods; however, at the reach scale, these coarse particles are essentially immobile in up to the 10-year or 50-year floods.

Based on the above analysis, the following can be stated about sediment on the WBDR:

- The WBDR channel lacks the competence to mobilize significant quantities of depositional material until flows are in excess of the 10-year or 50-year floods (competence limited).
- Coarse material within the aggradational features is relatively stable on decadal timescales.

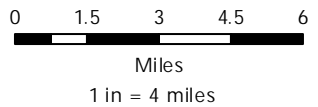
- The river's substrate is nonalluvial in origin, having been delivered to the valley by glacial processes several thousand years ago.
- Today, these sediments continue to be delivered to the valley floor by tributaries with more unit energy than the WBDR can achieve in the wide, shallow valley it has inherited.
- Analysis of historical aerial imagery and mapping reveals that the river's anabranching planform and many of the depositional features within the channel have been relatively unchanged over the past 70 to 80 years.
- This is the case both upstream and downstream of the reservoirs.



Legend

- Floodprone Communities
- River Station (miles)

WBDR FLOOD PRONE COMMUNITIES
 WEST BRANCH DELAWARE RIVER FLOOD STUDY - DS061
 FIGURE 4-4



4.3 High Risk Area #1 – Hancock

The village of Hancock is located at the confluence of the WBDR and the EBDR where the two branches meet to form the Delaware River proper. The village, located within the town of Hancock, is one of the larger communities along the West Branch (and East Branch) of the Delaware River. The village has a significant mix of uses, many of which are located along Front Street (Route 268). Measured just upstream of this confluence, the WBDR drains a 665-square-mile watershed. The village is located within the town of the same name. Sands Creek empties into the WBDR near the western extent of the village, adding 17.6 square miles to the WBDR's watershed. Assessment of the flooding hazard in the village from the EBDR is detailed in the Flood Mitigation Report for the EBDR.

The following land use types are within the area subjected to inundation during a 100-year flood (Tax Classification Codes in parentheses): Agricultural (100), Residential (200), Vacant Land (300), Commercial (400), Community Services (600), and Industrial (700). These include the following:

- Residential Homes
- Retail
- New York Susquehanna & Western Railway Corp. (NYSW) rail line

Figure 4-6 is an aerial image of the village of Hancock showing flood-prone areas, including roads and critical facilities.

Several buildings, including a Department of Public Works garage, lie adjacent to Sands Creek. What appear to be sidecast berms are intermittent along the stream bank. At the confluence of Sands Creek with the WBDR, the area between Route 17 and the railroad is within the WBDR's floodplain; flooding of this area by Sands Creek is likely influenced by tailwater controls from the WBDR.

The Route 191 bridge (BIN 1091700) that crosses into Pennsylvania was constructed in 1937 and is the final crossing of the WBDR before the confluence with the EBDR. This bridge is a moderate hydraulic constriction, causing as much as 1 foot or more of backwater inundation in the 10-, 50-, and 100-year floods and up to 1.7 feet of additional depths in the 500-year flood. A substantial aggradational feature has developed upstream of this bridge and appears to occlude the majority of the opening of the right (western) span of the crossing. This aging bridge is likely due for replacement in the coming decades. An upgraded structure should be accompanied by new hydrologic and hydraulic analyses that represent the conditions the bridge is likely to face over its design life.

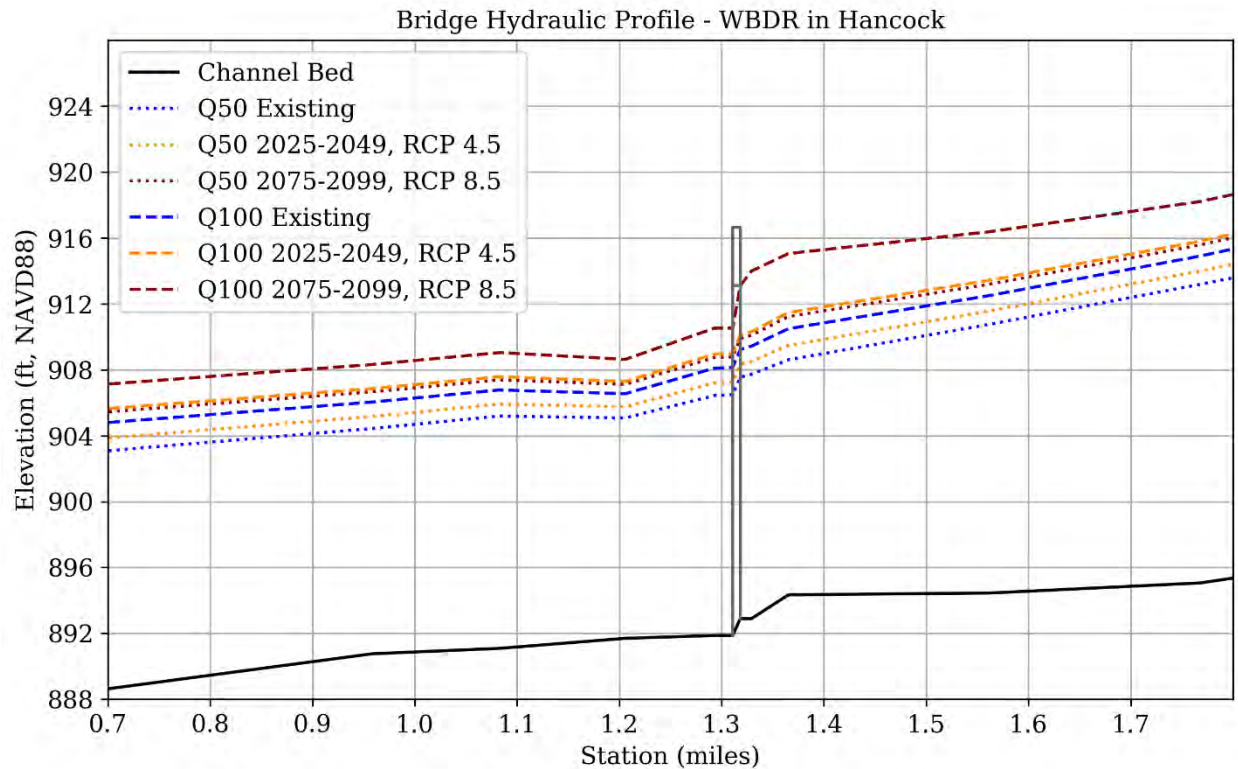


Figure 4-5: Hydraulic profiles of the WBDR at the Route 191 bridge in Hancock. Current and projected future flow profiles are shown.

West of the village between Hancock and Hale Eddy, the NY Susquehanna & Western (NYSW) Railroad is modeled as overtopping in the 50-year flood. Sands Creek Road (Route 67) crosses Sands Creek several times as it follows the tributary up its valley. The Sands and Cadosia Creek Watershed Assessments conducted by LandStudies in 2009 identified a number of conceptual flood mitigation and stream restoration alternatives. Updated hydraulic modeling of Sands Creek would enable quantitative assessment of these strategies and prioritization of infrastructure upgrades and stream rehabilitation projects.

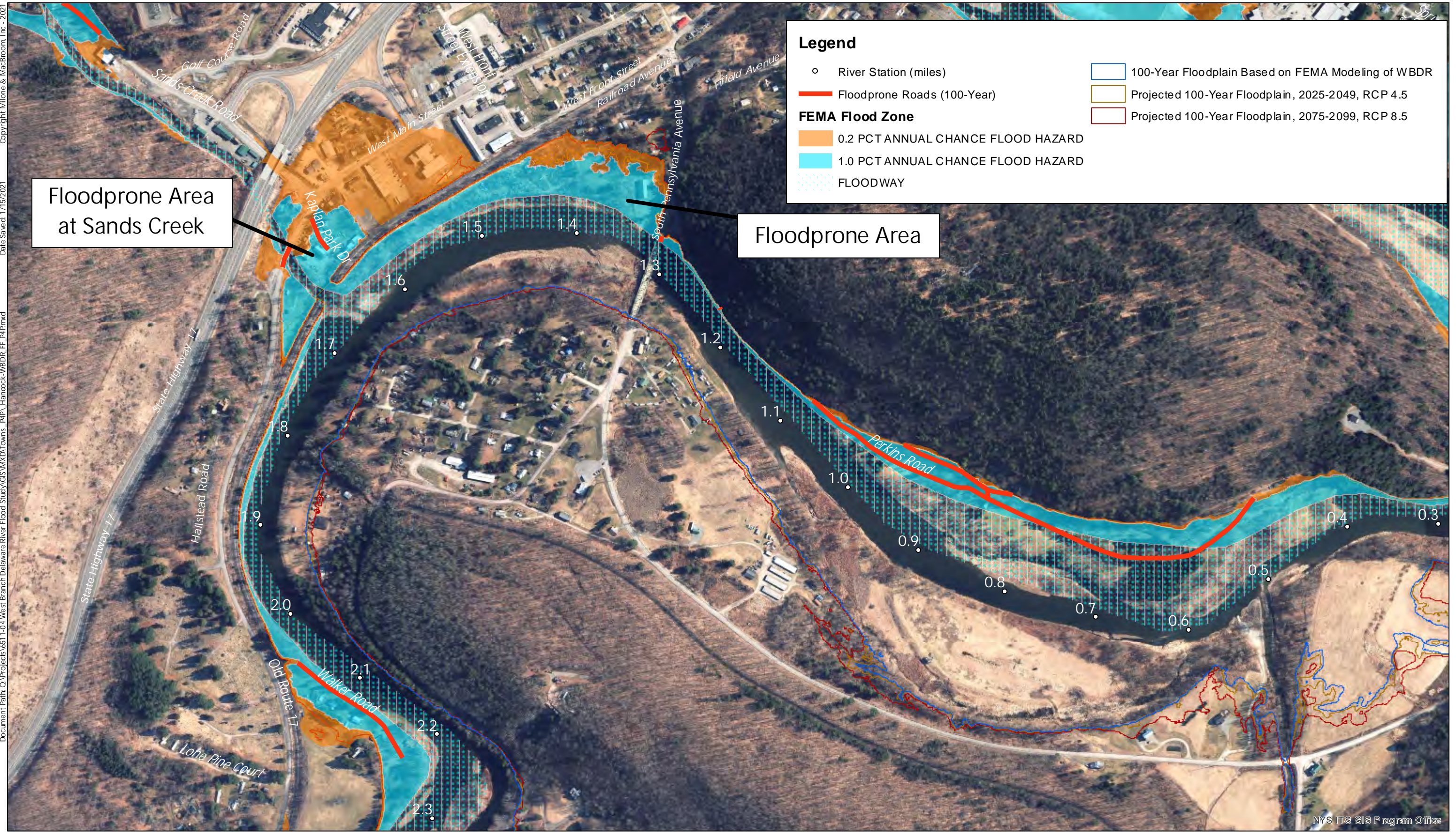


Photo 4-3: Railroad crossing of Sands Creek at its confluence with the WBDR. Note the cobble bar in the foreground.

Parcels have been identified through a Geographic Information System (GIS) analysis as being within the WBDR's 100- and 500-year floodplains in the Hancock area. In summary, the GIS identified 37 parcels with a total land area (not necessarily a flooded area – many parcels are only partially within a floodplain) of approximately 399 acres within the 100-year floodplain (most of this acreage is within five large parcels). The 500-year floodplain, which includes the 100-year floodplain, increases the area impacted by flooding, and the GIS identified an additional 18 parcels and 10 acres of land.

The 10-year floodplain in this area along the WBDR in Delaware County (southwest side, which is in the state of Pennsylvania) includes the floodway and generally areas at the bends of the West Branch. On the far west end of the study area, the floodwaters cover the inside bend where the river makes a nearly 90-degree turn to the north at the end of Walker Road, impacting residential properties. It extends inland a short distance at the mouth of the Sands Creek and then covers a significant amount of land on the inside bend along River Road, as well as a residence in this location, as the West Branch comes close to meeting up with the East Branch.

The 100-year floodplain in this area includes everything in the 10-year floodplain area, depths increase in these areas, and the floodplain generally extends further inland with the 100-year floodplain. The floodplain further impacts properties on the north side of the West Branch, the inside bend of the river, near Walker Road. The area subjected to floodwaters near the Sands Creek extends inland where the elevated railroad/berm stops the floodwaters, but it does extend inland slightly past the railroad bridge that extends across the creek. There is a business at the foot of the South Pennsylvania Avenue bridge and property located between the berm created by the railroad and the river that are inundated with a 100-year flood. There is a single residence and the road leading to it – River Road – that are inundated to a similar extent as a 10-year flood, but the water depths increase. Two additional residences near the confluence of the West Branch and EBDR have flooding in the vicinity, but the residences themselves are not within the floodplain.



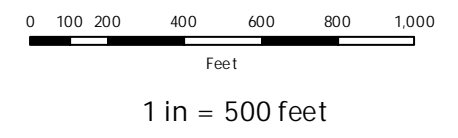
Legend

- River Station (miles)
- Floodprone Roads (100-Year)
- FEMA Flood Zone**
- 0.2 PCT ANNUAL CHANCE FLOOD HAZARD
- 1.0 PCT ANNUAL CHANCE FLOOD HAZARD
- ▨ FLOODWAY
- 100-Year Floodplain Based on FEMA Modeling of WBDR
- Projected 100-Year Floodplain, 2025-2049, RCP 4.5
- Projected 100-Year Floodplain, 2075-2099, RCP 8.5

Floodprone Area at Sands Creek

Floodprone Area

HIGH RISK AREA #1 - HANCOCK (WBDR & SANDS CREEK)
 WEST BRANCH DELAWARE RIVER FLOOD STUDY - SD061
 FIGURE 4-6



MILONE & MACBROOM
 231 MAIN STREET
 SUITE 102
 NEW PALTZ, NY 12561
 845.633.8153
 WWW.MMINC.COM

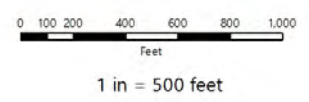


Legend

- River Station (miles)
- 100-Year Floodplain Based on FEMA Modeling of WBDR
- Projected 100-Year Floodplain, 2025-2049, RCP 4.5
- Projected 100-Year Floodplain, 2075-2099, RCP 8.5
- 0.2 PCT ANNUAL CHANCE FLOOD
- 1.0 PCT ANNUAL CHANCE FLOOD
- FLOODWAY

HIGH RISK AREA #1 - HANCOCK (WBDR & SANDS CREEK)
 WEST BRANCH DELAWARE RIVER FLOOD STUDY - SD061

- Potential Residential Relocation Area
- Potential Non-Residential Relocation Area



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Hancock (West Branch) Conceptual Redevelopment Locations

4.4 High Risk Area #2 – Hale Eddy

Hale Eddy is a hamlet located in the town of Deposit. Sherman Creek meets the WBDR at Hale Eddy, where this tributary's outwash delta comprises a significant portion of the hamlet's area. Here, the WBDR watershed covers 595 square miles, which includes the 19.2 square miles contributed by the Sherman Creek drainage. The USGS operates a stream flow gauge on the WBDR at the Hale Eddy bridge (014626500), which has been in operation since 1913.

This tight-knit area consisting of residences and agricultural lands is squeezed into the valley along the WBDR. Sherman Creek flows into the West Branch from the south between residential property and agricultural lands within Broome County right along the New York/Pennsylvania state line. Sherman Creek Road is carried over the West Branch and connects to Route 17 in Delaware County via an at-grade intersection.

The following land use types are within the area subjected to inundation during a 100-year flood (Tax Classification Code in parentheses): Residential (200), Vacant Land (300), Commercial (400), and Public Services (800). These include the following:

- Residential Homes
- Vacant Land



Photo 4-4: Coarse sediment aggradation at the confluence of Sherman Creek with the WBDR

Figure 4-8 is an aerial image of Hale Eddy showing flood-prone areas, including roads and critical facilities.

Several buildings are modeled as being inundated by the 50-year flood on the WBDR's left bank downstream of the Hale Eddy bridge and on the right bank upstream of the bridge. A number of cabins at the West Branch Angler Resort are modeled as flooding in the 50-year flood as well. Sections of Faulkener Road are susceptible to damage by the WBDR in flood events. Upstream of the hamlet, River Road is modeled as flooding in the 100-year flood but is vulnerable to damage in lesser flows as well.

Sherman Creek Road (Route 4) is a critical link in the route that follows the right bank of the WBDR and is susceptible to damage where it crosses Sherman Creek. Across the Pennsylvania state line, Sherman Road and Scott Center Road cross this tributary as well. Updated hydraulic modeling of Sherman

Creek would enable assessment of these crossings and identification of priority structures or sections of roadway.

The Hale Eddy bridge (BIN 3352290) carries Route 56/River Road/Sherman Creek Road/Hale Eddy-Broome County Line Road across the WBDR. This bridge was built in 2000 and is adequate to pass up to the current 100-year flood although over 2.5 feet of backwater develops at this structure in the 500-year flood. Depending on which of the projected future flow scenarios discussed in Section 2.3 bears out, it is possible that this structure would no longer pass the 100-year flood by the end of its design lifetime.

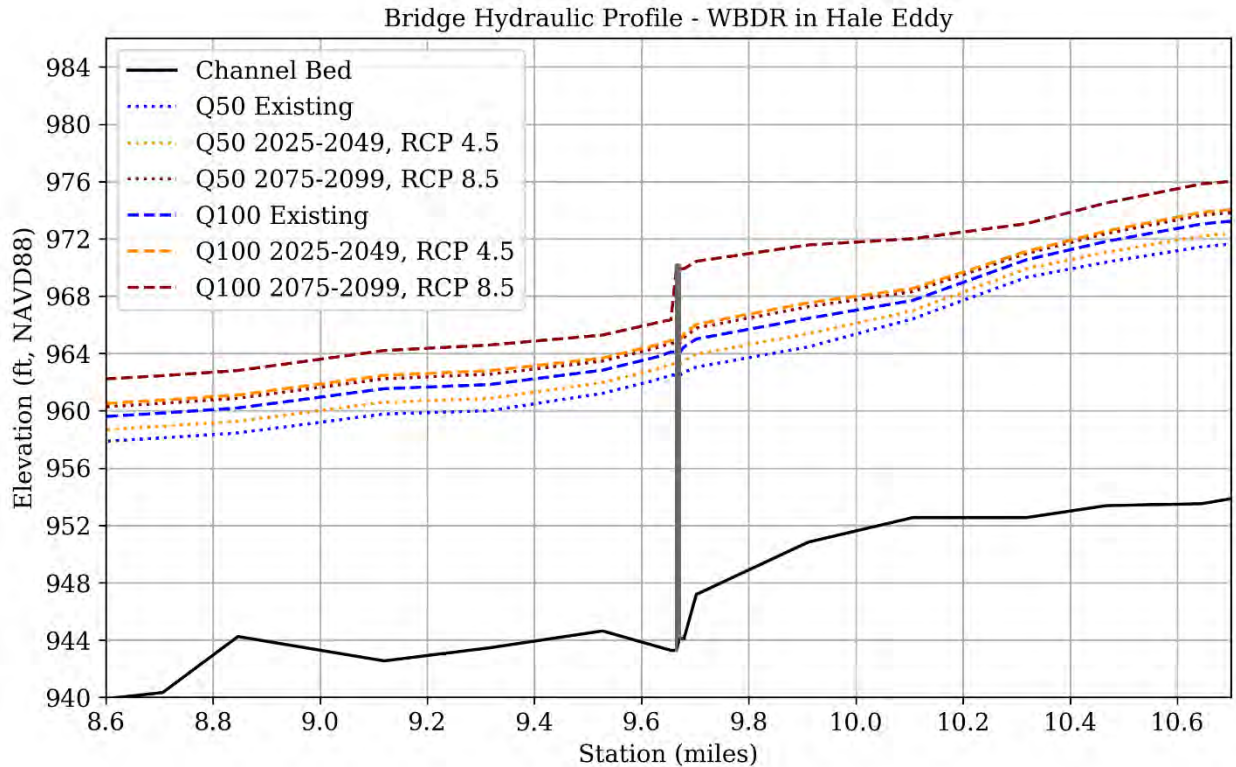


Figure 4-7: Hydraulic profiles of the WBDR at the Hale Eddy bridge. Current and projected future flow profiles are shown.

FIRM in the town of Sanford, on the WBDR's right bank, is currently based on a flood study dating to 1979. A modern FIS has been conducted for Broome County (36007CV001A, 2010) but has not yet been adopted. For the reasons discussed in Sections 2.3 and 2.4, preliminary floodplain mapping in some areas extends hundreds of feet beyond the limits of the effective boundary. In the vicinity of Hale Eddy, preliminary BFE is a remarkable 6 to 9 feet greater than the effective BFE. This affects several homes and properties on the WBDR's right bank; these residents are likely to be uninsured or underinsured through the NFIP. Unnecessary or avoidable property damage, injury, or death is possible due to the underrepresentation of the WBDR's SFHA per modern hydrological and hydraulic analyses. On the Delaware County side of the WBDR, floodplain mapping in Hale Eddy is based on the most recent FIS (36025CV001B, 2012). Residents are encouraged to consult the most recent products available from the FEMA Flood Map Service

Center (<https://msc.fema.gov/portal/home>) for a more complete understanding of the flood hazards that currently exist.

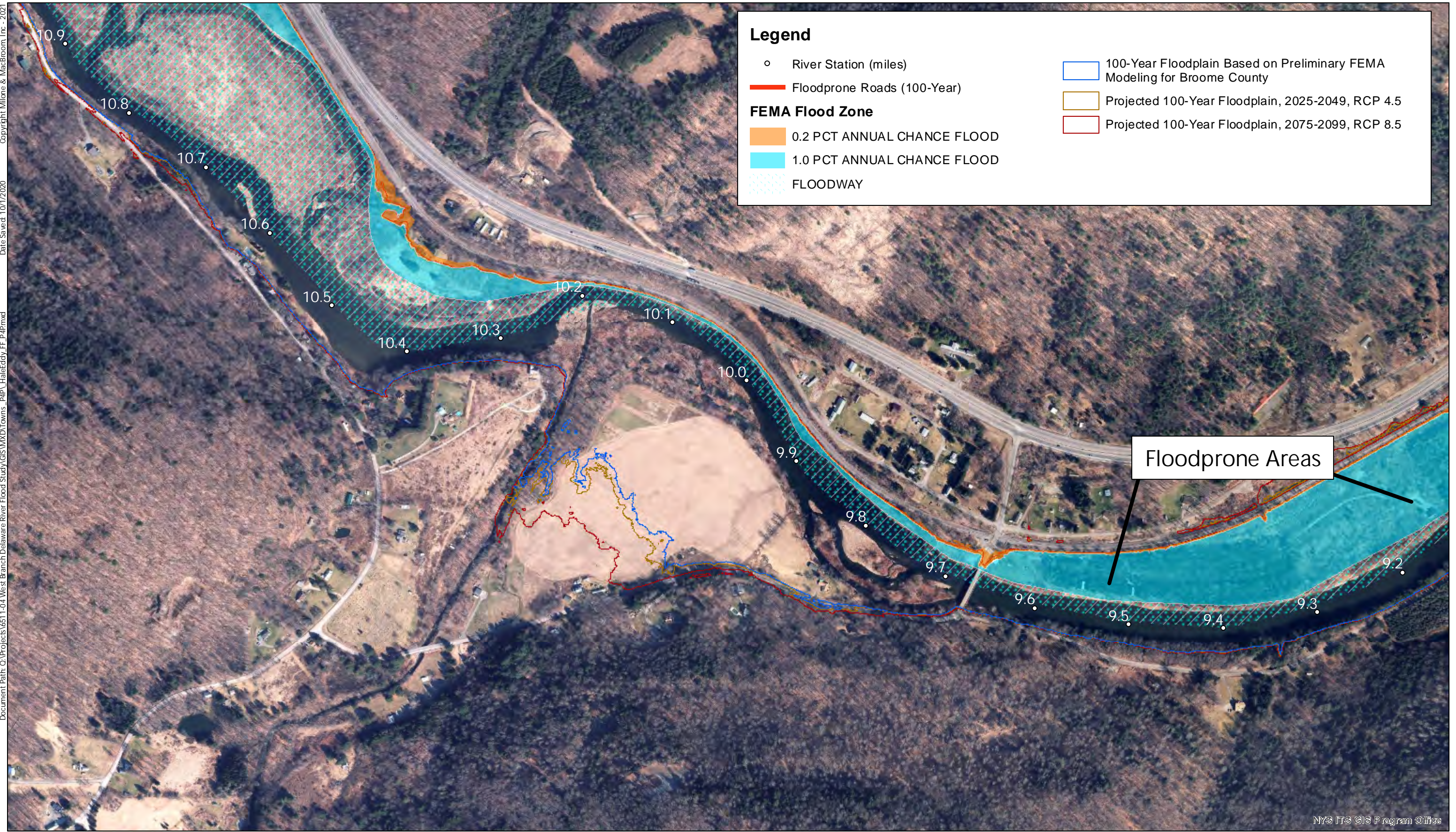
Hydraulic modeling has not been conducted on Sherman Creek; both effective and preliminary floodplain mapping on this tributary only represent the backwater inundation expected at its confluence with the WBDR. Development of a new hydraulic model to assess flooding hazards and mitigation strategies is recommended.

Parcels have been identified through a GIS analysis as being within the WBDR's 100- and 500-year floodplains in the Hale Eddy area. In summary, the GIS identified seven parcels with a total land area (not necessarily a flooded area – many parcels are only partially within a floodplain) of approximately 93 acres within the 100-year floodplain. The 500-year floodplain, which includes the 100-year floodplain, increases the area impacted by flooding, and the GIS identified an additional four parcels and 11 acres of land.

The 10-year floodplain in this area along the WBDR includes the floodway and the lowland areas along the river generally from the west until the Sherman Creek Road bridge. On the far west end of the study area, the 10-year floodplain covers the island and much of the interior bend of the river near Evans Road. The floodwater is contained between the raised railroad line and the river where in several places the 10-year floodplain reaches the rail line. Further southeast, the inside bend of the river at the mouth of the Sherman Creek (in Broome County) south to the bridge is inundated along the creek and into the cleared fields. To the southeast of the bridge, there is a smaller area of flood-prone land on the northern bank of the river where there are several residences at the end of a long common driveway.

The areas subjected to floodwaters during a 100-year flood in this area are the same as those of the 10-year floodplain, but flooding extends inland significantly in some areas, and depths are increased. The island to the northwest of the developed area and much of the agricultural area from Sherman Creek Road northwest to the Sherman Creek (in Broome County) are covered, and depths increase. A large parcel located on the inside bend of the West Branch just downstream of the island is within the floodplain. On the north side of the river, the floodplain is generally contained between the berm created by the railroad line and the river, which minimizes the amount of area flooded on the north side of the West Branch in some places; however, flooding does impact residential properties, and the depths are again more significant. Sherman Creek meets the WBDR at Hale Eddy (in Broome County) where this tributary's outwash delta comprises a significant portion of the hamlet's area. Back on the north side of the river in Delaware County, flooding inundates the land from the Sherman Creek Road bridge southeast generally up to the railroad line. There are several residences located along the river in this location.

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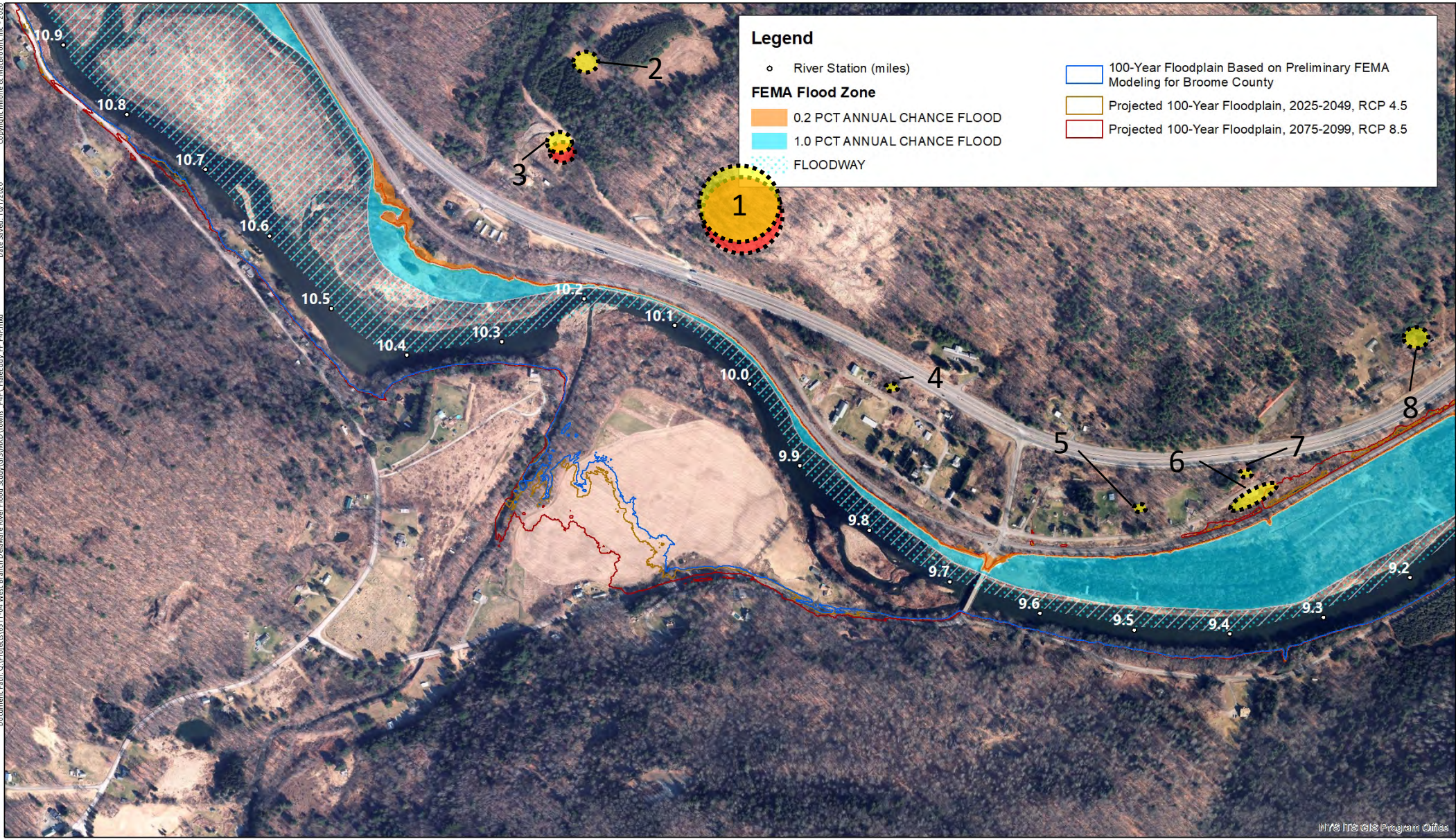


HIGH RISK AREA #2 - HALE EDDY (WBDR & SHERMAN CREEK)



WEST BRANCH DELAWARE RIVER FLOOD STUDY - SD061

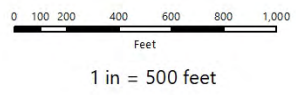
FIGURE 4-8

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HIGH RISK AREA #2 - HALE EDDY (WBDR & SHERMAN CREEK)
WEST BRANCH DELAWARE RIVER FLOOD STUDY - SD061

 Potential Residential Relocation Area
 Potential Non-Residential Relocation Area



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Hale Eddy Conceptual Redevelopment Locations

4.5 High Risk Area #3 – Deposit

Deposit is a village located on the WBDR within the towns of Deposit and Sanford, in Delaware and Broome Counties, respectively. Oquaga Creek and Butler Brook join the WBDR at Deposit. Oquaga Creek is the largest of the WBDR's tailwater tributaries, draining a 68-square-mile watershed; a dam in North Sanford near the stream's headwaters regulates flow from about 4.5 square miles.

This mixed-use village is the largest community along the tailwaters of the WBDR and has direct access to Route 17. Deposit spans both the northwest and southeast banks of the West Branch. Oquaga Creek flows through the southern portion of the village, entering the West Branch just north of the Route 17 bridge while the Butler Brook flows through the northern edge of the village and enters the West Branch in close proximity to the Deposit High School.

The following land use types are within the area subjected to inundation during a 100-year flood: (Tax Classification Code in parentheses): Residential (200), Vacant Land (300), and Public Services (800). These include the following:

- Residences
- Commercial and Retail
- Industrial Uses
- High School Campus and Associated Playing Fields
- Restaurants
- Religious Institutions

The USGS has periodically operated a flow gauge on Oquaga Creek near its confluence with the WBDR (01426000). Peak stream flow data are available for water years 1941-1973 and 2003-2009; the highest recorded flow at this site occurred during the 2006 flood. Stream gauging provides valuable data for a variety of applications, and analyses gain dependability and utility as the period of record grows. It may take several decades for newly installed gauging stations to collect sufficient data for reliable statistical analyses, so it is important to maintain the continuity of existing records whenever possible. It is recommended that the Village of Deposit and Town of Sanford work with the USGS to resume operation of this gauging station at or near its former location.

Figure 4-10 is an aerial image of Deposit showing flood-prone areas, including roads and critical facilities.

Hydraulic modeling of Oquaga Creek was last conducted in the late 1970s. It is recommended that this be updated based on modern hydrological and hydraulic analyses of the stream and its watershed. This will enable assessment of flood-prone areas, bridge hydraulics, and at-risk infrastructure and property. Bone Creek is a small, steep tributary that joins Oquaga Creek in the village. It is piped underground for several hundred feet and daylighted at Front Street. It is recommended that the culvert be assessed for capacity and adequacy. If it is found to be undersized, upgrading the structure or restoration of a natural channel can be explored.

Much of downtown Deposit is subject to inundation in the 100-year flood, with considerable areas expected to flood in the 10-year event as well. The majority of the village is prone to flooding in the 500-year event. Oquaga Creek and Butler Brook, which run through downtown Deposit, can contribute to flooding in the village along with or independently of the WBDR. Erosion issues at the Fireman's Park along Oquaga Creek have been reported. In the village of Deposit, more than 100 properties lie within the effective SFHA; over 250 properties fall inside the preliminary SFHA.

The Deposit Village Police Department, Volunteer Fire Department, Emergency Medical Services, Emergency Operations Center, the Deposit Town Hall and Village Hall, the Sanford Town Highway Garage, US Post Office, a New York Department of Motor Vehicles location, and a New York State Electric and Gas (NYSEG) power substation are all located within the preliminary SFHA. It is anticipated that these critical facilities and services would be significantly affected by a 100-year flood, and emergency services may be forced to operate at a substantially diminished capacity during such an event. It is recommended that critical facilities be relocated to outside the preliminary SFHA. Meanwhile, identify and secure alternate locations on high ground that can be used to store essential equipment if a flood is forecasted, including fire apparatuses, ambulances, and highway construction equipment.

Deposit's wastewater treatment facility sits at the confluence of Oquaga Creek and the WBDR. Preliminary FEMA modeling indicates that about half of the facility is expected to flood by up to 2 feet in the 10-year flood; the entire area is modeled as flooding in a 50-year flood. In a 100-year flood, inundation depths of up to 8 feet are expected at this location. Over \$990k was spent repairing the facility following the 2006 flood (Tetra Tech, 2013). Due to the primary constraint of a wastewater treatment facility (gravity), relocating the plant to high ground is not likely practical, so floodproofing measures based on preliminary BFE are recommended.

The village features a historic district along the right bank of the WBDR, much of which is mapped in the river's regulatory floodway according to FEMA's preliminary FIS. South of the village corporate limits, several homes line the WBDR on its left bank along with an industrial area. Here, the effective regulatory flood zones are delineated based on the most recent FIS for Delaware County (36025CV001B). These properties on Airport Road all lie within the floodway and are expected to be impacted by flows exceeding the 10-year flood. Anecdotal reports confirm that this area is prone to frequent flooding that restricts access.



Photo 4-5: View looking upstream on the WBDR from the confluence of Oquaga Creek (lower left of image). The Pine Street/Oak Street bridge can be seen in the distance underneath the left (viewer's right) span of the NYSW railroad bridge.

In Deposit, the flood of 2006 was slightly in excess of a 100-year event on the WBDR. The SFHA predicted by recent FEMA modeling was met or exceeded throughout the village; hundreds of buildings incurred flooding damage. While devastating to the affected communities, this flood provided the opportunity for rigorous calibration and validation of FEMA's hydraulic model, so it is unfortunate that the most recent flood mapping has not yet been adopted.

Preliminary FEMA modeling indicates that the Pine Street/Oak Street bridge (BIN 1007640) over the WBDR, built in 1990, will pass the 10-year flood, but the 50-year event will overtop the approach roadway and flood downtown Deposit. However, this bridge does not cause significant additional backwater flooding in the village except in the modeled 500-year flood. A NYSW railroad bridge spans the WBDR about 1,400 feet downstream of the Pine Street/Oak Street bridge. This crossing causes slight backwaters but does not significantly increase flooding extents except in the 500-year flood wherein it may result in more than a 4-foot increase in upstream water surface elevation. A depositional bar has developed at this bridge's central pier. Both of these bridges are predicted to become hydraulically inadequate in modeled future flow scenarios. The Route 17 bridges (Westbound BIN: 1013331; Eastbound BIN: 1013332) are unconventionally represented in the FEMA hydraulic model but are not expected to significantly contribute to backwater flooding. These were built in 1961.

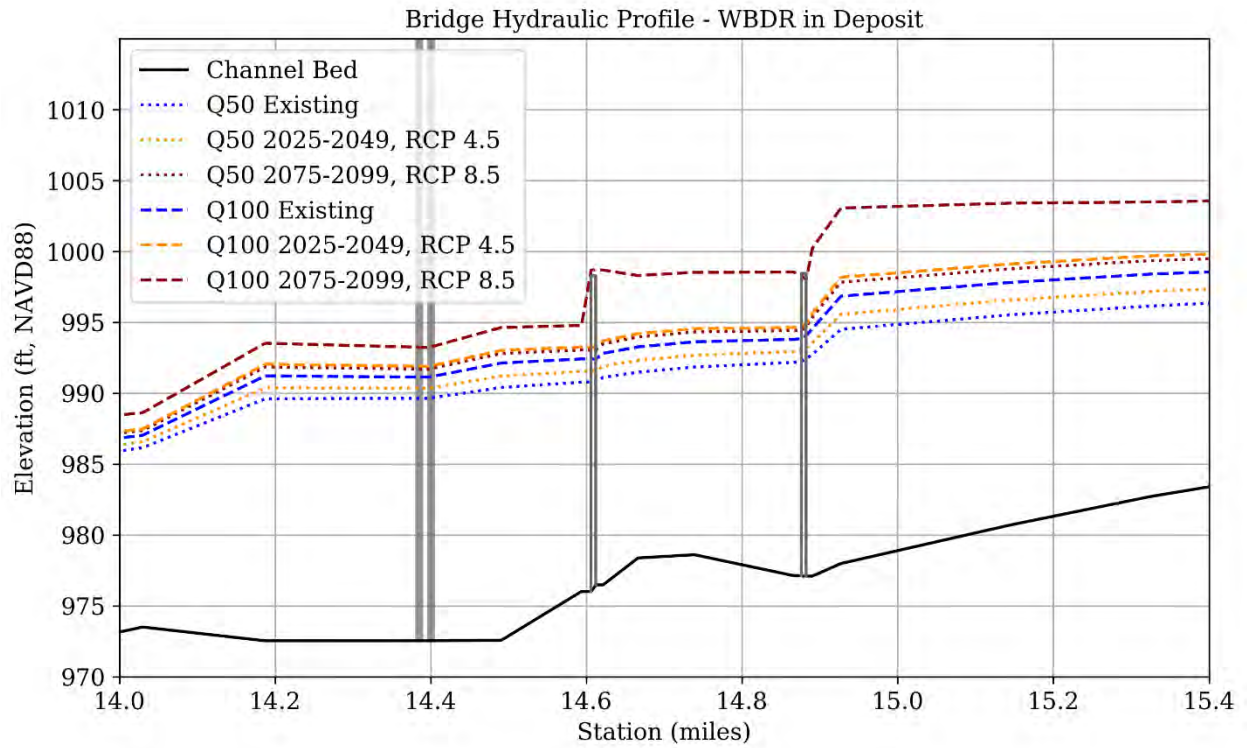


Figure 4-9: Hydraulic profiles of the WBDR in Deposit, showing the Route 17, NYSW Railway, and Oak Street bridges. Current and projected future flow profiles are shown.



Photo 4-6: Portion of an aerial photograph acquired in May 1942, showing the village of Deposit. Note aggradation at the center pier of the railroad bridge over the WBDR and at the confluence with Oquaga Creek. These features were present long before construction of the Cannonsville Reservoir. The new Route 17 had not yet been constructed. Retrieved from the USGS Earth Resources Observation and Science Center's *EarthExplorer* online service.

According to the most recent hydraulic modeling of the WBDR, most of downtown Deposit is subject to inundation in the 100-year flood. This includes many of the roads in the village, including critical primary routes such as Main Street, Front Street, Second Street, Elm Street, Wheeler Street, and Laurel Bank Road. The Pine Street/Oak Street bridge across the WBDR would be entirely inaccessible due to flooding of all approach roadways on the river's right bank. Near the Mill Street bridge over Oquaga Creek, Mill Street, Oquaga Lake Road, Scott Center Road, and Dublin Street are expected to be impassible due to backwater flooding from the WBDR; further inundation and damage are likely if Oquaga Creek is flooding simultaneously. Water up to 4 feet deep is expected at the low point in Mill Street where it passes under the NYSW railroad.

Flood insurance rate mapping in the village of Deposit is currently based on a flood study dating to 1978. A modern FIS has been conducted for Broome County (36007CV001A, 2010) but has not yet been adopted. For the reasons discussed in Sections 2.3 and 2.4, preliminary floodplain mapping extends several hundred feet beyond the limits of the effective boundary. Preliminary BFE is as much as a staggering 7 feet greater than the effective BFE. This affects dozens of homes and properties in Deposit, and many of these residents are likely to be uninsured or underinsured

through the NFIP. Unnecessary or avoidable property damage, injury, or death is possible due to the underrepresentation of the WBDR's SFHA per modern hydrological and hydraulic analyses. Residents are encouraged to consult the most recent products available from the FEMA Flood Map Service Center (<https://msc.fema.gov/portal/home>) for a more complete understanding of the flood hazards that currently exist.

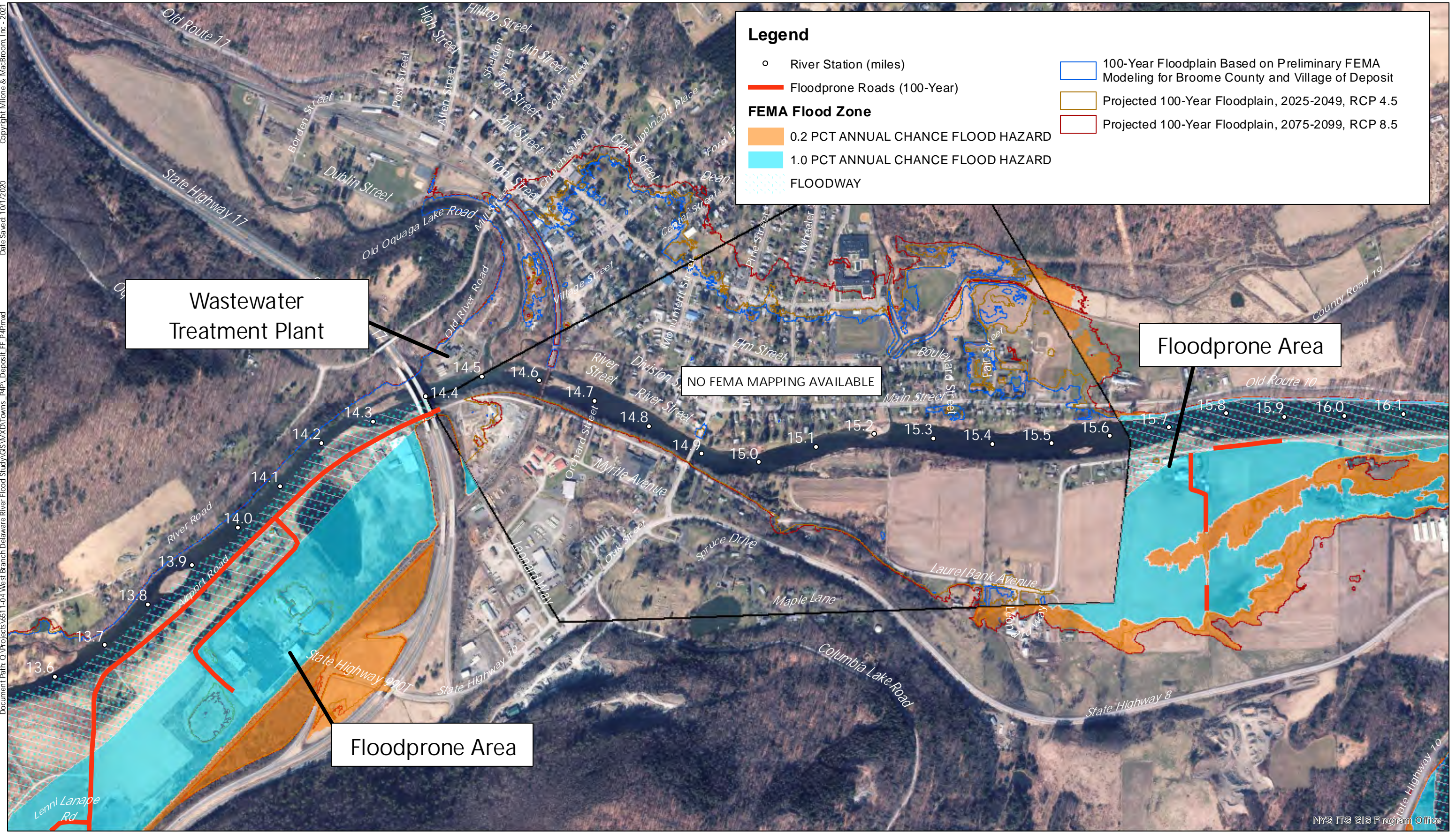
Parcels have been identified through a GIS analysis as being within the WBDR's 100- and 500-year floodplains in the Deposit area. In summary, the GIS identified 252 parcels with a total land area (not necessarily a flooded area – many parcels are only partially within a floodplain) of approximately 676 acres within the 100-year floodplain. The 500-year floodplain, which includes the 100-year floodplain, increases the area impacted by flooding, and the GIS identified an additional 28 parcels and 44 acres of land.

The 10-year floodplain in this area along the WBDR includes the floodway and the scattered areas along the river, including the industrial park area to the southwest of Route 17, the area around the mouth of the Oquaga Creek in Delaware County (extending into the village in Broome County), and on scattered sites within the village east of the creek generally along the Butler Creek but also extending inland in the area of Front and 2nd Streets. Floodwaters inundate residential property at the foot of the Pine Street Extension bridge on the northwest side of the river. The agricultural land between Laurel Bank Road and the river (in the town of Deposit, just to the northeast of the village) is also inundated generally up to the two 90-degree turns in the road, with scattered flooding in the fields around the structures to the east of the bends in the road.

The areas subjected to floodwaters during a 100-year flood in this area are the same as those of the 10-year floodplain, but a 100-year flood includes a significant amount of land and developed property, and depths are increased. The area subjected to floodwaters during a 100-year flood extends inland on the southeast side of the West Branch along Laurel Bank Road/Route 48, again in proximity to the two 90-degree bends in the road near the Cattle Company property and then along a line generally along Laurel Bank Road to Pine Street.

On the northwest side of the West Branch, the area subjected to floodwaters during a 100-year flood covers more than half the village in Delaware County and several blocks in Broome County. This area starts along Main Street in close proximity to Warner Field, covering the road and property between the ballfield and the river. The area subjected to floodwaters covers Main Street adjacent to the apartments and, once south of the apartment property, extends inland, significantly encompassing residences along Boulevard Street and Elm Street. Property along Butler Creek behind the high school property and the ballfield/track all the way to the West Branch and along a line generally running behind homes along 2nd Street to Pine Street is inundated. At Pine Street, the 100-year floodplain extends even further inland, covering Pine Street to the Delaware County line (which is in the middle of the village). This entire area from Pine Street to the West Branch is within the floodplain, except the raised rail line.

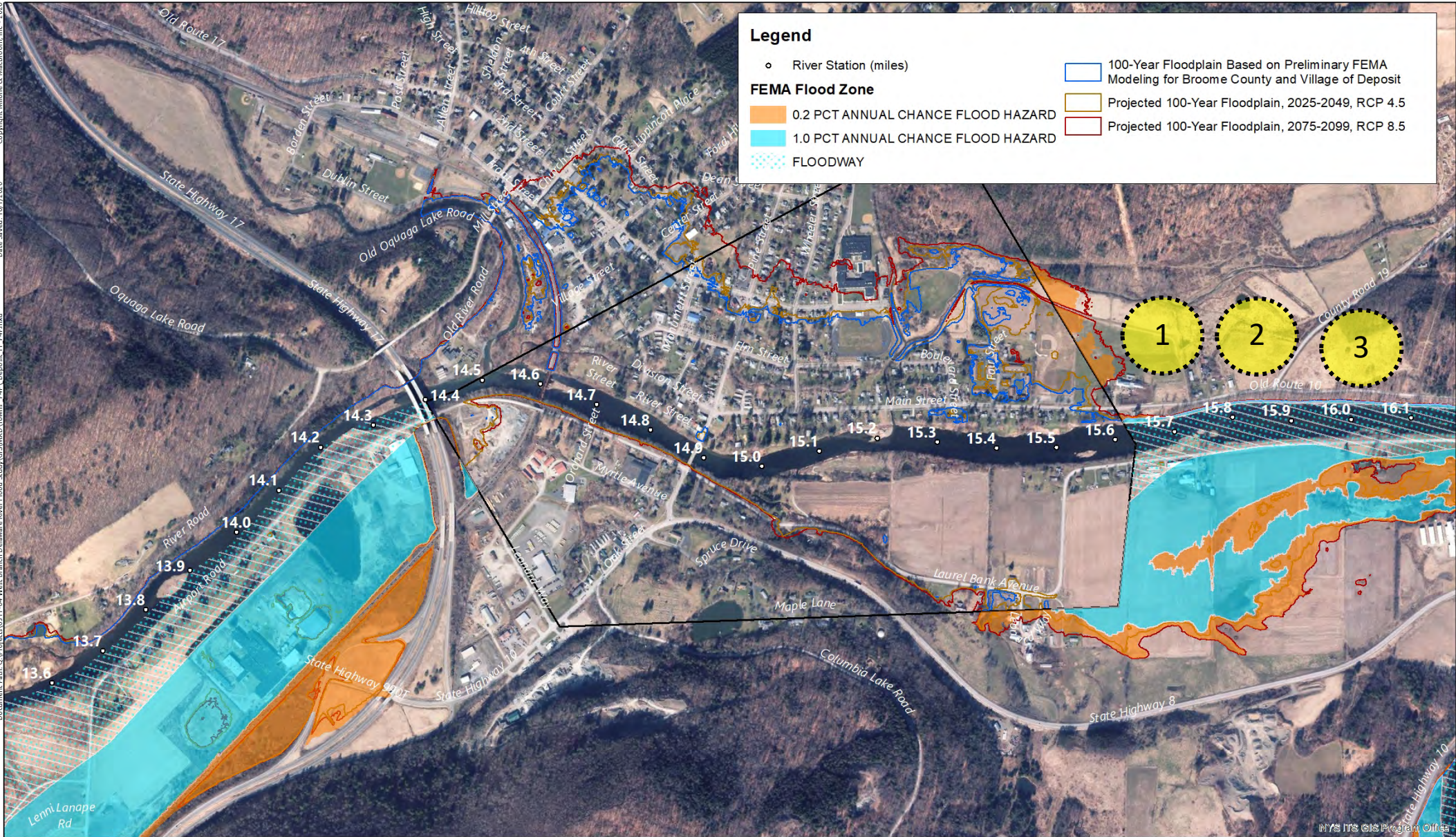
In the southernmost corner of the village within Delaware County, an industrial property abutting Route 17 at the bridge over the West Branch that appears to store natural materials, such as stone, is partially within the area subjected to floodwaters during a 100-year flood. Southeast of the Route 17 bridge, the floodplain covers almost all the land within the area between the West Branch and Route 17, with the exception of the rail line and Route 17, covering the industrial park area served by Airport Road.



HIGH RISK AREA #3 - DEPOSIT (WBDR & OQUAGA CREEK)

WEST BRANCH DELAWARE RIVER FLOOD STUDY - SD061

FIGURE 4-10

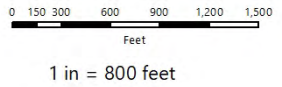


Legend

- River Station (miles)
- 100-Year Floodplain Based on Preliminary FEMA Modeling for Broome County and Village of Deposit
- 0.2 PCT ANNUAL CHANGE FLOOD HAZARD
- 1.0 PCT ANNUAL CHANGE FLOOD HAZARD
- FLOODWAY
- Projected 100-Year Floodplain, 2025-2049, RCP 4.5
- Projected 100-Year Floodplain, 2075-2099, RCP 8.5

HIGH RISK AREA #3 - DEPOSIT (WBDR & OQUAGA CREEK)
 WEST BRANCH DELAWARE RIVER FLOOD STUDY - SD061

- Potential Residential Relocation Area
- Potential Non-Residential Relocation Area



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Deposit Conceptual Redevelopment Locations

4.6 High Risk Area #4 – Stilesville

Stilesville is a hamlet located in the town of Deposit, at the confluence of Cold Spring Creek and the WBDR. The USGS operates a stream flow gauge on the WBDR in Stilesville at the weir just downstream of the Cannonsville Dam. Of the communities along the WBDR tailwaters, Stilesville is nearest to the Cannonsville Dam and benefits most from the reservoir's flood control services although ultimately these are unreliable. However, the hamlet has historically experienced relatively frequent flooding from the WBDR and Cold Spring Creek. Most flood-prone buildings in the hamlet are located close to the confluence of the two watercourses.

This small, primarily residential area just upstream from the village of Deposit sits on both sides of the WBDR just below the Cannonsville Reservoir dam. There are agricultural uses in this area as well as some industrial properties.

The following land use types are within the area subjected to inundation during a 100-year flood (Tax Classification Code in parentheses): Agricultural (100), Residential (200), Vacant Land (300), Commercial (400), Community Services (600), and Public Services (800).

These include the following:

- Residential Homes
- Cattle Company
- Lodging

Figure 4-12 is an aerial image of Stilesville showing flood-prone areas, including roads and critical facilities.

According to FEMA modeling, the NYCDEP access road bridge over the WBDR immediately downstream of the Cannonsville Dam does not appear to be a significant hydraulic constriction and does not contribute to flooding in Stilesville. This bridge is projected to have freeboard in the modeled 500-year flood event. The Route 8 bridge (BIN 1007660) constricts the channel somewhat but is still modeled as passing the 100-year flood with only minimal influence on floodwater surface profiles; the four-span bridge was built in 1990. The approach roadway and parts of the bridge deck are expected to overtop in the 500-year flood but not result in significant additional inundation depths. A depositional bar has developed at this bridge's central pier.

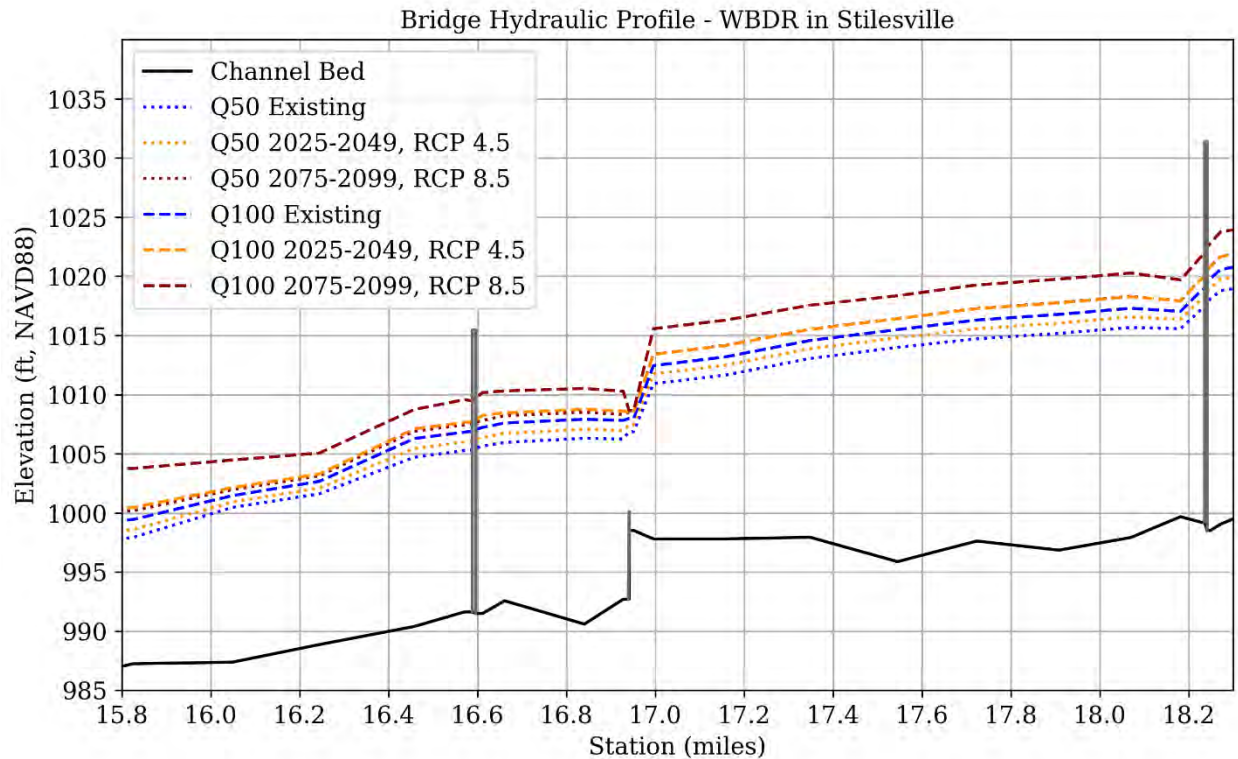


Figure 4-11: Hydraulic profiles of the WBDR in Stilesville, showing the Route 8 bridge. Current and projected future flow profiles are shown.

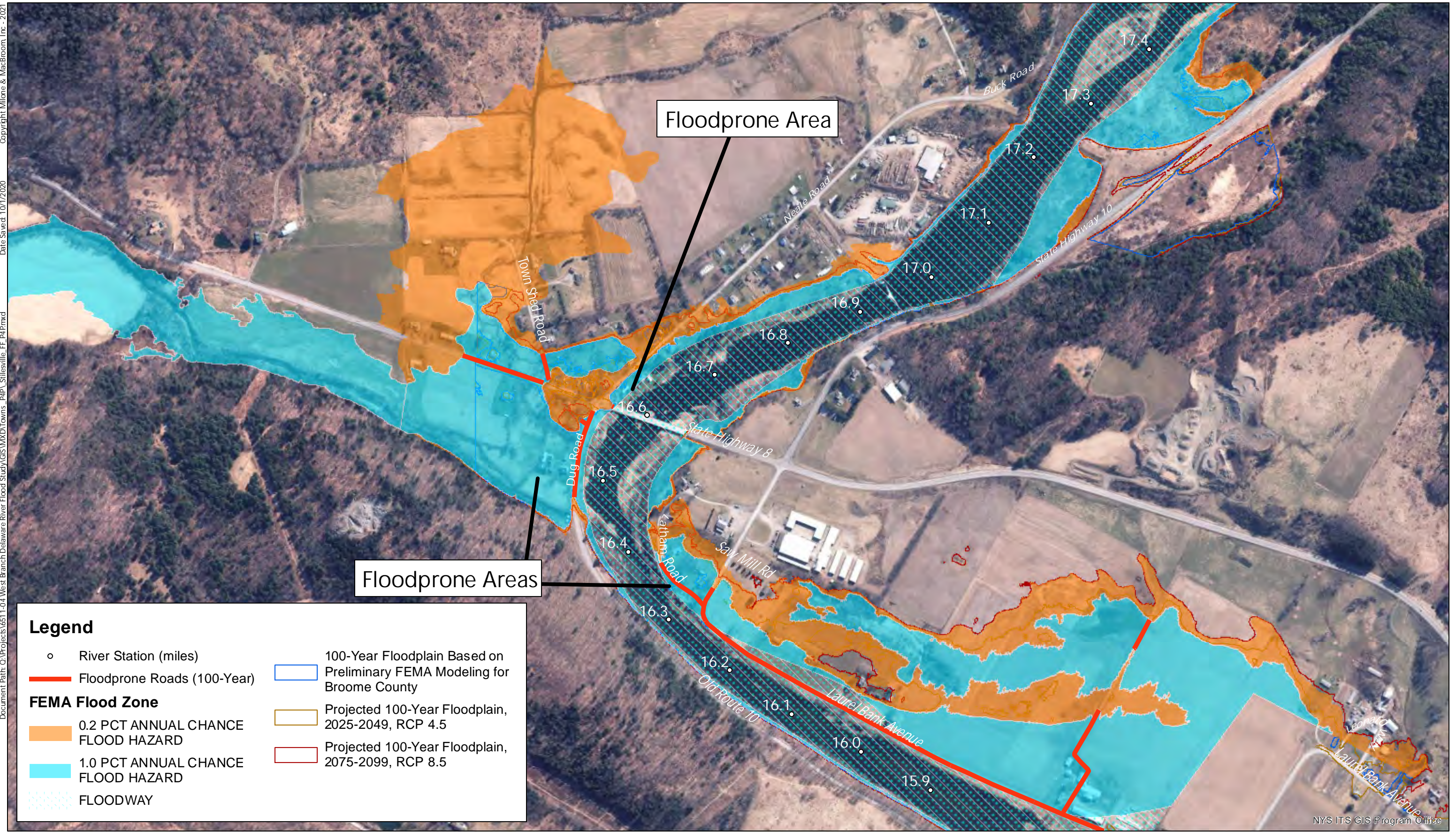
Dug Road crosses Cold Spring Creek with a twin-barrel corrugated metal pipe (CMP) arch culvert just upstream of its meeting with the WBDR. The left (eastern) culvert barrel has partially collapsed, and a considerable amount of cover fill has washed into the breach. It is recommended that this condition be repaired as soon as is practical. New hydraulic modeling of this tributary stream is also recommended and may suggest that a replacement crossing is necessary. In general, single-span structures are preferable to multiple culvert barrels, which may foster sediment aggradation and are prone to debris and ice jamming.

Route 8 follows Cold Spring Creek and subsequently its East Branch up the valley to the north and east; Route 20 follows the creek's main stem to the north. These roads are critical detour routes in case of flooding in the WBDR valley and are susceptible to damage by these energetic tributary streams. Inundation of low-lying sections of Schofield Road and washouts of Michigan Hollow Road have been reported.

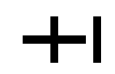
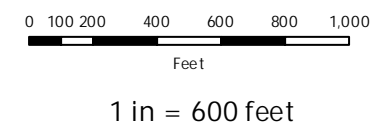


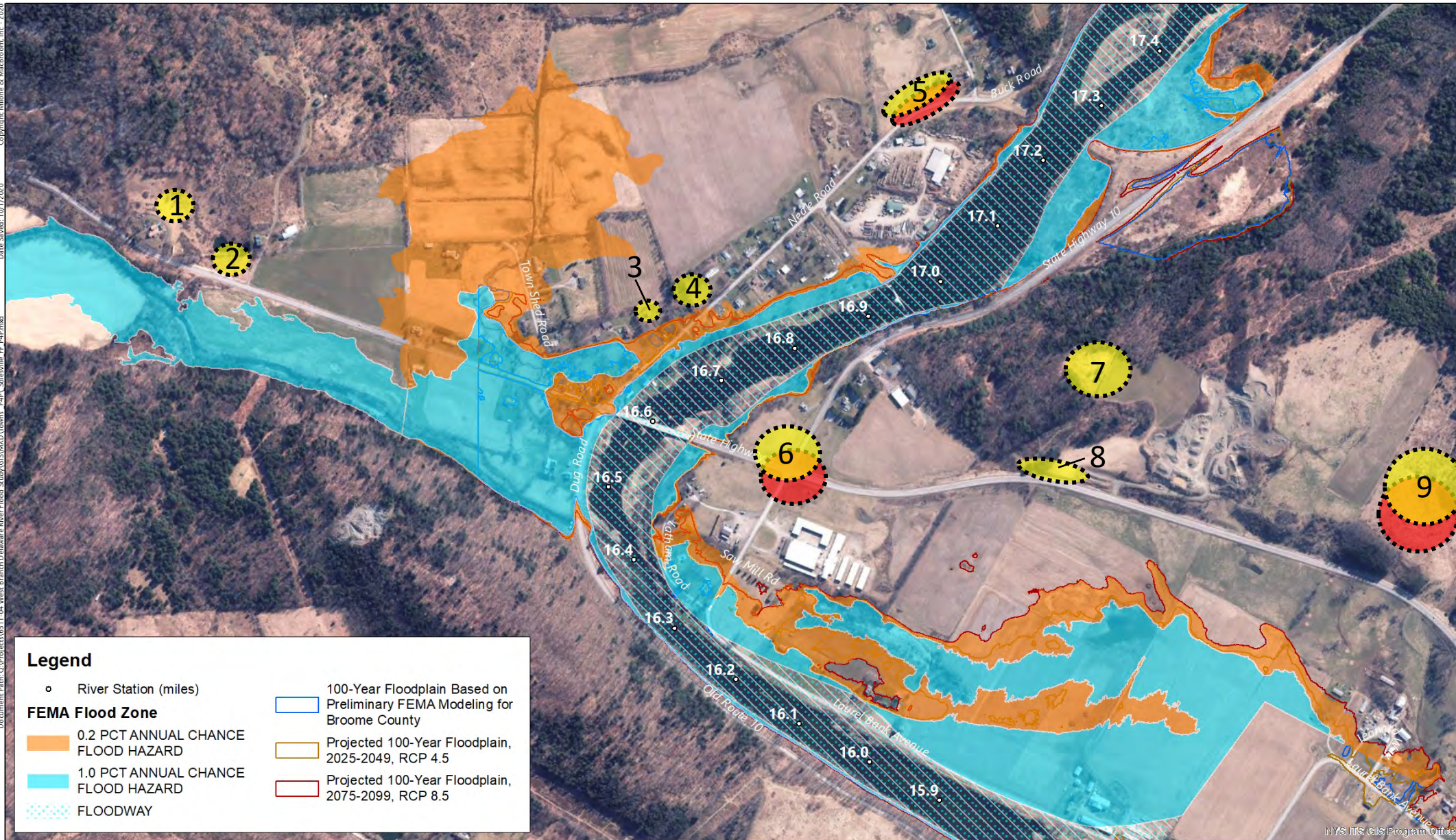
Photo 4-7: Damaged culvert carrying Dug Road over Cold Spring Creek at its confluence with WBDR. View looking upstream. Corrugated arch panels in east barrel have separated, and cover fill is eroding into the creek. Also note sediment aggradation in intermediate slack water.

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HIGH RISK AREA #4 - STILESVILLE (WBDR & COLD SPRING CREEK)
WEST BRANCH DELAWARE RIVER FLOOD STUDY - SD061
FIGURE 4-12



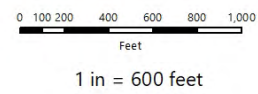


Legend

- River Station (miles)
- FEMA Flood Zone**
- 0.2 PCT ANNUAL CHANCE FLOOD HAZARD
- 1.0 PCT ANNUAL CHANCE FLOOD HAZARD
- FLOODWAY
- 100-Year Floodplain Based on Preliminary FEMA Modeling for Broome County
- Projected 100-Year Floodplain, 2025-2049, RCP 4.5
- Projected 100-Year Floodplain, 2075-2099, RCP 8.5

HIGH RISK AREA #4 - STILESVILLE (WBDR & COLD SPRING CREEK)
 WEST BRANCH DELAWARE RIVER FLOOD STUDY - SD061

- Potential Residential Relocation Area
- Potential Non-Residential Relocation Area



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Stilesville Conceptual Redevelopment Locations

Parcels have been identified through a GIS analysis as being within the WBDR's 100- and 500-year floodplains in the Stilesville area. In summary, the GIS identified 135 parcels with a total parcel land area (not necessarily a flooded area – many parcels are only partially within a floodplain) of 3,837 acres within the 100-year floodplain. The 500-year floodplain, which includes the 100-year floodplain, increases the area impacted by flooding, and the GIS identified an additional 23 parcels and 238 acres of land.

The 10-year floodplain in this area along the WBDR includes the floodway and land on the inside of the bend between Latham Road and the river. While residential properties are inundated, there are no residential structures within the floodplain in this location. On the northern side of the river, the land along the Cold Spring Creek is inundated, including some residential structures located along Dug Road. There is also some floodplain area along the river east of the Route 8 bridge upstream of the dam, particularly at the foot of the bridge on the southern side of the river.

The areas subjected to floodwaters during a 100-year flood in this area are the same as those of the 10-year floodplain, but a 100-year flood includes more land area, and depths are increased. The area subjected to floodwaters during a 100-year flood in this area extends inland quite significantly on the southern side of the West Branch along Route 10 upstream from the Route 8 bridge. Flooding encroaches on properties on both the inside and outside of the bend in the river, with floodwater extending inland between Beebe Hill Road and the woodland hillside to the east.

Downstream past the bend, the area subjected to floodwaters during a 100-year flood extends inland along Laurel Bank Road/Route 48 to the village of Deposit limits.

5.0 RECOMMENDATIONS

At varying degrees of intensity over the past few centuries, the WBDR and its tributaries have experienced dredging, berming, straightening, channelization, damming, and relocation to one or the other valley wall. Historically, these efforts were often targeted at flood control, maximizing agricultural land, minimizing bridge crossings, powering grist and sawmills, and maintaining clear channels for log drives. Current flood mitigation and stream restoration efforts are frequently constrained by the development that grew along these heavily modified waterways; communities sprung up around the timber, bluestone, railroad, agriculture, and mill industries that concentrated along the most extensively altered rivers and streams. Today, the communities remain but without many of the industries that had spurred their growth along the riverbanks. Our understanding of river morphology and flood dynamics has advanced significantly since the days of tributary mill dams, acid factories, and log drives on the WBDR, and these villages and hamlets now find themselves caught in the middle. It is easy to understate just how significantly these streams have been modified over the years, so unfortunately, in many cases, it is difficult to design meaningful flood mitigation projects without altering the affected communities.

It is common for historical channel modification practices to instigate long-term instability issues that can exacerbate the flooding damages that are experienced today. For this reason, regulatory agencies rarely allow these activities without extensive review, and permitted debris clearing and public funding availability are generally limited to flood recovery efforts. These practices simply maintain a stream's impaired state without addressing the source of the impairment, which is why some of the most effective flood mitigation projects are also river restorations. By accommodating the streams' natural tendencies, flooding damages and property loss can be substantially alleviated. However, it is difficult for restoration and flood mitigation projects to establish stable conditions that reduce flood hazards without providing space for some degree of natural floodplain functions or alluvial fan processes to occur. In developed areas, this may require reclamation of property; removal of berms; or relocation of flood-prone homes, businesses, infrastructure, or critical facilities.

Where practical, tributary stream restoration projects should be associated with adjacent infrastructure improvements. This will help avoid repetitive losses. In the WBDR basin, the roadways that follow tributary valleys are critical detour routes but themselves can be highly susceptible to flooding damage. A holistic approach to improving infrastructure resiliency can include a combination of stream rehabilitations, bridge and culvert upgrades, roadway relocations, drainage improvements, asset consolidation and, in some cases, strategic disinvestment.

5.1 Relocations

In Section 4.0 of this report, Flood Mitigation Analysis, the analysis and discussion for each flood-prone community along the WBDR includes a relocation master plan. The relocation plans are intended to be used on a voluntary basis by county planners, municipalities, and individual property owners to guide potential relocation out of and away from flood-prone areas. They are intended to be flexible and may be implemented by one property owner, or by several, or by a residential neighborhood or business district. The plans are intended to provide options for relocations to occur within a community.

Recommendation:

- Implement voluntary relocation of flood-prone homes and businesses out of areas that are prone to flooding. (Relocation Mater Plans are provided in Section 4.0 for each flood-prone community.)

5.2 Channel Restoration and Floodplain Enhancement

Channel restorations in developed areas often involve what is called floodplain benching, or creation of a multistage channel. This is a process wherein adjacent land on one or both sides of the stream channel is excavated to a specified depth to provide additional flow conveyance in flood events. The normal, or low-flow, channel can be sized to accommodate a range of considerations, including sediment transport equilibrium and aquatic organism habitat. The floodplain bench elevation is set to a specific flood flow, which could be anywhere from fairly frequent (even annually) to a relatively rare 5- or 10-year event. This will depend on the goals and constraints of individual projects. In some cases, two or more tiers or stages of benches can be designed to address more unique situations with multiple or conflicting objectives.

When flows spill onto these benches, the river's energy dissipates across the floodplain, reducing erosive forces in the channel. As floodwaters rise, the combination of the channel plus floodplain bench effectively acts as one much larger channel. These generally require minimal maintenance and can be designed to convey some of the most severe floods but only as long as enough space is available alongside the river. In some cases, this may only affect fields, forests, or maybe backyards and parking lots, but in more built-up areas, removal or relocation of buildings and infrastructure may be necessary. These topics can be very complex and difficult for property owners, businesses, and communities as a whole and must be considered individually and objectively. In some of the smaller tributary communities, these decisions may approach the existential; after performing relocations necessary for a flood mitigation project, there would be nothing left to save from flooding.

One of the important dynamics in the WBDR basin is the prodigious volume of sediment that is delivered to the valley floor by the river's tributaries, which must be considered in restoration design in this watershed. While this is a natural process, many of these tributaries are heavily incised due to encroaching development and infrastructure, both historical and modern. This impaired state has fostered headcutting and bank failures that contribute massive quantities of sediment to the stream. As previously discussed, much of this sediment is deposited once the stream's energy diminishes; this can fill entrenched channels that run through communities, clog bridges and culverts, and cause channel avulsions. The preferred course of action is to address the source of the surplus sediment proactively. Recommendations include stabilizing active bank failures and setting grade controls to inhibit headcutting as part of stream restoration projects on these tributaries. There is an emergent need for up-to-date hydraulic modeling on these streams to assess both the existing flood hazard as well as mitigation alternatives in each unique setting.

Recommendations:

- Implement channel restoration projects, including floodplain reconnection and enhancement, bank stabilization, and grade controls. These actions are recommended along Cold Spring Creek, Oquaga Creek, Sherman Creek, and Sands Creek as they approach more settled areas near their confluences with the WBDR.
- In some cases, relocations may be necessary before channel restoration projects can be implemented.
- Additional or enhanced hydraulic models are necessary.

5.3 Replacement of Undersized Bridges

Overall, most bridges over the WBDR are adequately sized, and many do not contribute to backwater flooding except in the most extreme events. This is no doubt in some part a product of the river's prolific history of flooding; undersized bridges simply did not last. However, modeling indicates that some bridges may pressurize in severe floods, which may enhance the potential for scour damage. Other bridges will have their approach roadways overtopped. This can provide valuable relief to the bridge but leaves the route impassable and often damaged. For this reason, it is critical for residents to heed flood warnings and evacuation recommendations; rescue operations can be extremely hazardous to both evacuees and first responders alike and are often avoidable.

Depositional bars are omnipresent in the slack waters downstream of bridge piers. Replacement bridges should seek to minimize the number of piers to discourage aggradation that reduces the available hydraulic opening.

When bridges are replaced, remove all substructural or foundational elements of the old structure that may impede, constrict, or otherwise deleteriously impact the conveyance of flood flows. Examples include relic abutments that continue to contract flood flows or pier bases and pile caps that can foster sediment aggradation in the slack waters they create.

Upon visual inspection, many bridges and culverts on tributary streams appear undersized, and anecdotal reports of backwater flooding, roadway and bridge deck overtopping, and sediment or debris jamming confirm these observations. In some cases, this is also reflected in FEMA modeling from the 1970s and 1980s although stream alignments have changed, and a number of bridges have been replaced since that time. Quantitative recommendations are not possible without up-to-date hydraulic modeling of tributary streams; however, it is recommended that all new bridge and culvert crossings be designed to adhere to or exceed current applicable requirements and guidelines from the New York State Department of Transportation (NYSDOT) and NYSDEC.

Roadway improvements and stream restorations should seek to minimize the number of stream crossings where possible or practical. Hydraulically adequate stream crossings can be costly to design and construct, especially in settings with such dynamic sediment transport conditions. To improve infrastructure and transportation network resiliency, reducing the total number of bridges by relocating roads can be more efficient than replacing multiple bridges. This should be considered where appropriate.

As discussed in Section 2.3: Hydrology, estimated flood flows on the WBDR have increased considerably over recent decades. It is therefore recommended that a new hydrologic analysis of flood flows on the river be performed prior to future bridge replacements to ensure that structures are adequately sized. The most modern accepted future-flow projections or climate change scenario estimates should be applied to accommodate the bridge's design life.

5.4 Operation of Cannonsville Reservoir

As detailed in Section 4.1 of this report, the Cannonsville Reservoir provides flood mitigation benefits to downstream communities on the WBDR despite the fact that it is not managed exclusively for flood control. These benefits are highly variable, depending both on downstream distance from the reservoir and void at the inception of the flood event. While ultimately responsible to the DRBC for its operations, it may be possible to enhance the dam's flood control capabilities if release capacity were increased, which would facilitate more dynamic void management. There may also be ancillary benefits to the entire Delaware River.

Recommendations:

- It is recommended that NYCDEP and DRBC explore the feasibility of upgrading the Cannonsville Reservoir's outlet works to meet applicable low-level drain and impoundment evacuation requirements per NYSDEC. In addition to bringing the dam up to modern safety standards, this could also facilitate far more dynamic void management strategies as well as the ability to perform more geomorphologically significant conservation releases.

5.5 Adoption of Preliminary FIS and Updated FEMA Hydraulic Models

It is recommended that Broome County, including the Town of Sanford and the Village of Deposit, adopt the most recent preliminary FIS, dated February 5, 2010, (36007CV001A), and associated FIRM. As detailed in Section 3.3, these products more accurately represent the flood hazards that exist in these areas and would help ensure that those property owners who are at risk have access to the NFIP.

Many areas in the WBDR basin are at risk of flooding damages from the river's many tributary streams. Most of these were last modelled in the 1970s and 1980s using the antiquated HEC-2 software; many have never been modeled. It is recommended that new modeling of these tributaries be developed to reflect current hydraulic and hydrologic conditions. These updated models may be used to devise flood mitigation strategies that address the specific priorities of individual communities.

Recommendations:

- For the safety and security of residents and their properties, it is highly recommended that jurisdictions in Broome County, including the Town of Sanford and the Village of Deposit, adopt the 2010 Preliminary FIS and associated floodplain mapping developed for the county.
- Seek new or updated, enhanced hydraulic models for tributaries to the WBDR.

- Maintain and update hydraulic modeling to reflect changes such as bridge replacements, flood mitigation projects, or updated flood hydrology. When appropriate, seek Letters of Map Change (LOMC) through FEMA to ensure the SFHA is accurately represented, and residents have adequate coverage through the NFIP.

5.6 Sediment Management

Tributary sediment loading can be reduced by stabilizing mass failures and installing appropriate grade control structures to prevent further channel incision and arrest active headcuts. The larger sediments delivered by these tributaries cannot be easily transported by the WBDR, so where aggradation threatens property and infrastructure, it is generally more effective to intercept sediments or stabilize their source farther upstream. In some cases, sediment traps, with comprehensive operation plans, may be appropriate. Proactive approaches are far more effective than reactive responses such as dredging.

Local representatives often report a sentiment that dredging will alleviate flooding along the WBDR. Dredging and debris removal are often the first, and occasionally misguided, responses to flooding. Dredging for flood control is futile; the source of the issue is not addressed, and more often than not, the very next flood will cause the very same problem. Overwidening or overdeepening through dredging can initiate instability (including bed and bank erosion), may foster poor sediment transport, and will not necessarily provide significant flood mitigation. Sediment removal can further isolate a stream from its natural floodplain, disrupt sediment transport, expose erodible sediments, cause upstream bank or channel scour, and encourage additional downstream sediment deposition. Improperly dredged stream channels often show signs of severe instability, which can cause larger problems after the work is complete. Such a condition is likely to exacerbate flooding on a long-term basis.

A sound sediment management program sets forth standards to delineate how, when, and to what dimensions sediment excavation should be performed. Sediment excavation requires regulatory approvals as well as budgetary considerations to allow the work to be funded on an ongoing or as-needed basis as prescribed by the standards to be developed. Conditions in which active sediment management should be considered include for the purpose of infrastructure protection or at bridge openings where hydraulic capacity has been compromised.

In cases where sediment excavation in the stream channel is necessary, a methodology should be developed that would allow for proper channel sizing and slope. The following guidelines are recommended:

1. Maintain the original channel slope and do not overly deepen or widen the channel. Excavation should not extend beyond the channel's estimated bankfull width unless it is to match an even wider natural channel.
2. Sediment management should be limited in volume to either a single flood's deposition or to the watershed's annual sediment yield in order to preclude downstream bed degradation from lack of sediment. Annual sediment yields vary, but one approach is to use a regional average of 50 cubic yards per square mile per year unless a detailed study is made.

3. Excavation of fine-grained sediment releases turbidity. Best available practices should be followed to control sedimentation and erosion.
4. Sediment excavation requires regulatory permits. Prior to initiation of any in-stream activities, NYSDEC should be contacted, and appropriate permitting should be obtained.
5. Disposal of excavated sediments should always occur outside of the floodplain. If such materials are placed on the adjacent bank, they will be vulnerable to remobilization and redeposition during the next large storm event.
6. No sediment excavation should be undertaken in areas where aquatic-based rare or endangered species are located.

5.7 Riparian Buffers

The Natural Resources Conservation Service (NRCS) (2016) defines a riparian buffer as, "a corridor of trees and/or shrubs planted adjacent to a river, stream, wetland or water body." The definition continues to note that the width of the buffer and the distance of the buffer from the waterbody are essential characteristics determining the functioning of the buffer.

The benefits provided by riparian buffers to their adjacent waterbodies have been well documented. These benefits can include those to the physical stability of the stream as well as those to habitat and water quality.

The physical benefit of a riparian buffer to a stream has been shown to include increased stability, reduced stream bank erosion, and reduced channel migration. Scientific studies have found that intertwining roots within a stream bank can increase stream bank strength, increase resistance to erosion caused by high flows, and provide greater channel stability (Sweeney and Newbold, 2014). One study found that following major floods bank erosion was 30 times more prevalent on stream bends without forests than those with forests (Beeson and Doyle, 1996). Other studies have also shown that forested stream reaches exhibit slower channel migration and thus provide more stability than deforested channels (Hession et al., 2003; Allmendinger et al., 2005). The NRCS (2016) notes that stabilized stream banks also help maintain the geometry of the stream, including characteristics such as the meander length and profile.

The dimensions of the riparian buffer have been shown to play an important role in the functioning of the buffer. Burckhardt and Todd (1998) found that streamside forests with widths of around 10 meters (approximately 33 feet) provide some protection from channel migration. Similarly, Zaines et al. (2006) found bank erosion was lowered significantly by the presence of a streamside forest approximately 33 feet wide along reaches within an agricultural landscape. Sweeney and Newbold (2014) found that the influence of vegetation appears to be greatest when the roots extend to the toe of banks (Thorne, 1990; Anderson et al., 2004). Otherwise, the stream bank is susceptible to erosion from the stream as it flows. According to the NRCS Practice Standard for Riparian Forest Buffers, the minimum width should be at least 35 feet from the top of the bank.

In terms of the vegetation making up the riparian buffer, the NRCS recommends utilizing native species, if available, that are the following:

- Adapted to the soil and climate of the planting site
- Water-loving or water-tolerant species and tolerant of extended periods of flooding (depending on the width of the planting and distance from the stream banks)
- Moderate to aggressive root and crown spread to occupy the site quickly and provide adequate litter fall
- Resistant to pests and herbicides (if adjacent to farmland)

The benefits of riparian buffers to habitat include providing food and cover for wildlife and shade that helps to lower water temperatures. Buffers can also increase habitat diversity in several ways; the addition of large woody debris to a stream provides habitat to a range of species, and a reduction in sedimentation helps prevent silt from covering large rocks or stones and from filling pools in the streambed, both of which serve as habitat. In terms of improvements in water quality, buffers have been shown to protect water resources from pollutants in surface runoff, such as sediment and nutrients. Vegetated riparian buffers serve to slow water velocity, thus allowing sediment to settle out of the runoff water. The nitrogen and phosphorus attached to the sediment settle out of the surface runoff as well. To a lesser extent, dissolved nitrogen and phosphorus and other pollutants can be sequestered, degraded, and processed in the riparian buffer.

Establishment of riparian buffers is recommended in areas along the WBDR and its tributaries where cleared land currently reaches right to the stream bank. Priority should be placed on areas with active bank erosion or lateral channel migration.

5.8 Road Closures

Approximately 75 percent of all flood fatalities occur in vehicles. Shallow water flowing across a flooded roadway can be deceptively swift and wash a vehicle off the road. Water over a roadway can conceal a washed out section of roadway or bridge. When a roadway is flooded, travelers should not take the chance of attempting to cross the flooded area. It is not possible to tell if a flooded road is safe to cross just by looking at it.



One way to reduce the risks associated with the flooding of roadways is their closure during flooding events, which requires effective signage, road closure barriers, and consideration of alternative routes.

According to FEMA modeling, historical documentation, and anecdotal reporting, flood-prone roads exist throughout the WBDR basin. Flooding can occur from the WBDR, tributary streams, or both. In many cases, small, unnamed tributaries and even roadside drainage ditches frequently cause washouts or other significant damage to roadways, culverts, and bridges. Drainage issues and flooding of smaller tributary streams are generally not reflected in FEMA modeling, so local

public works and highway departments are often the best resource for identifying priority areas and repetitively damaged infrastructure.

5.9 Stormwater Runoff Storage

Runoff from small, frequent rain events may be intercepted by both natural and man-made storage areas. These can be highly beneficial for water quality and may help to mitigate certain isolated or localized chronic issues with stormwater infrastructure. However, small storage areas scattered throughout the watershed are not capable of causing a meaningful reduction of peak flows in the extreme events that are the focus of this report, such as the 100-year flood. This can generally only be accomplished by very large dams or massive wetland complexes that dominate basin hydrology (e.g., Bellu et. al 2016, Watson et. al 2016, Trueheart et. al 2020).

Existing wetlands in the watershed provide a vital function by storing stormwater during floods and releasing it gradually downstream, thereby reducing peak flows. Protecting the functions and values of remaining existing wetlands is recommended. Several important NYSDEC-regulated freshwater wetlands occur on tributaries to the WBDR. The 20.4-acre Whitaker Swamp in Broome County is part of Whitaker Swamp State Forest at the headwaters of a tributary to the WBDR. An 18.5-acre wetland is located at the headwaters of Hungry Hollow in Delaware County. A 14.8-acre wetland is in Delaware County within the watershed of Roods Creek, a WBDR tributary. The 20.3-acre Pine Swamp is located along Pine Swamp Brook, a tributary to Sands Creek. NWI mapping of the watershed indicates that smaller wetlands occur along many of the WBDR tributaries.

5.10 Individual Property Flood Protection

A variety of measures are available to protect existing public and private properties from flood damage. While broader mitigation efforts are most desirable, they often take time and money to implement. On a case-by-case basis where structures are at risk, individual floodproofing should be explored. Property owners within FEMA-delineated floodplains should also be encouraged to purchase flood insurance under the NFIP and to make claims when damage occurs.

Communities within the WBDR basin should work to identify and remove vacant and abandoned structures to prevent future hazards. In areas where properties are vulnerable to flooding, improvements to individual properties and structures may be appropriate. Potential measures for property protection include the following:

Elevation of the structure – Home elevation involves the removal of the building structure from the basement and elevating it on piers to a height such that the first floor is located at least 2 feet above the level of the 100-year flood event. The basement area is abandoned and filled to be no higher than the existing grade. All utilities and appliances located within the basement must be relocated to the first-floor level or installed from basement joists or similar mechanism.

Construction of property improvements such as barriers, floodwalls, and earthen berms – Such structural projects can be used to prevent shallow flooding. There may be properties within the basin where implementation of such measures will serve to protect structures.

Dry floodproofing of the structure to keep floodwaters from entering – Dry floodproofing refers to the act of making areas below the flood level watertight and is typically implemented for commercial buildings that would be unoccupied during a flood event. Walls may be coated with compound or plastic sheathing. Openings such as windows and vents can be either permanently closed or covered with removable shields. Flood protection should extend only 2 to 3 feet above the top of the concrete foundation because building walls and floors cannot withstand the pressure of deeper water.

Wet floodproofing of the structure to allow floodwaters to pass through the lower area of the structure unimpeded – Wet floodproofing refers to intentionally letting floodwater into a building to equalize interior and exterior water pressures. Wet floodproofing should only be used as a last resort. If considered, furniture and electrical appliances should be moved away or elevated above the 100-year flood elevation.

Performing other home improvements to mitigate damage from flooding – The following measures can be undertaken to protect home utilities and belongings:

- Relocate valuable belongings above the 100-year flood elevation to reduce the amount of damage caused during a flood event.
- Relocate or elevate water heaters, heating systems, washers, and dryers to a higher floor or to at least 12 inches above the BFE (if the ceiling permits). A wooden platform of pressure-treated wood can serve as the base.
- Anchor the fuel tank to the wall or floor with noncorrosive metal strapping and lag bolts.
- Install a backflow valve to prevent sewer backup into the home.
- Install a floating floor drain plug at the lowest point of the lowest finished floor.
- Elevate the electrical box or relocate it to a higher floor and elevate electric outlets.

Encouraging property owners to purchase flood insurance under the NFIP and to make claims when damage occurs – While having flood insurance will not prevent flood damage, it will help a family or business put things back in order following a flood event. Property owners should be encouraged to submit claims under the NFIP whenever flooding damage occurs in order to increase the eligibility of the property for projects under the various mitigation grant programs.

6.0 FUNDING SOURCES

Funding for bridge and culvert replacements and other infrastructure upgrades is often scarce in small communities. In a 2017 survey of county, city, town, and village officials in New York State (NYS) conducted by Aldag et al. of Cornell University, 80 percent of responders reported that infrastructure needs contribute to local fiscal stress, and 86 percent said that fiscal stress affects local infrastructure budgeting. The consequence is that local governments that are fiscally stressed are likely to have substantial needs for infrastructure investment but must defer addressing them (NYS Comptroller, 2017). Because of this, external funding is often necessary, and a concerted effort is required to secure these grants although small local governments may not have staff available to dedicate to these endeavors.

Several funding sources may be available for the implementation of recommendations made in this report. These and other potential funding sources are discussed in further detail below. Note that these may evolve over time as grants expire or are introduced.

Emergency Watershed Protection Program (EWP)

Through the EWP program, the U.S. Department of Agriculture's NRCS can help communities address watershed impairments that pose imminent threats to lives and property. Most EWP work is for the protection of threatened infrastructure from continued stream erosion. NRCS may pay up to 75 percent of the construction costs of emergency measures. The remaining costs must come from local sources and can be made in cash or in-kind services. EWP projects must reduce threats to lives and property; be economically, environmentally, and socially defensible; be designed and implemented according to sound technical standards; and conserve natural resources.

FEMA Pre-Disaster Mitigation (PDM) Program

The PDM program was authorized by Part 203 of the Robert T. Stafford Disaster Assistance and Emergency Relief Act (Stafford Act), 42 U.S.C. 5133. The PDM program provides funds to states, territories, tribal governments, communities, and universities for hazard mitigation planning and implementation of mitigation projects prior to disasters, providing an opportunity to reduce the nation's disaster losses through PDM planning and the implementation of feasible, effective, and cost-efficient mitigation measures. Funding of pre-disaster plans and projects is meant to reduce overall risks to populations and facilities. The PDM program is subject to the availability of appropriation funding as well as any program-specific directive or restriction made with respect to such funds.

<https://www.fema.gov/pre-disaster-mitigation-grant-program>



FEMA Hazard Mitigation Grant Program (HMGP)

The HMGP is authorized under Section 404 of the Robert T. Stafford Disaster Relief and Emergency Assistance Act. The HMGP provides grants to states and local governments to implement long-term hazard mitigation measures after a major disaster declaration. The purpose of the HMGP is to reduce the loss of life and property due to natural disasters and to enable mitigation measures to be implemented during the immediate recovery from a disaster. A key purpose of the HMGP is to ensure that any opportunities to take critical mitigation measures to protect life and property from future disasters are not "lost" during the recovery and reconstruction process following a disaster.



The HMGP is available only in the months subsequent to a federal disaster declaration in the State of New York. Because the state administers the HMGP directly, application cycles will need to be closely monitored after disasters are declared in New York.

<https://www.fema.gov/hazard-mitigation-grant-program>

FEMA Flood Mitigation Assistance (FMA) Program

The FMA program was created as part of the National Flood Insurance Reform Act (NFIRA) of 1994 (42 U.S.C. 4101) with the goal of reducing or eliminating claims under the NFIP. FEMA provides FMA funds to assist states and communities with implementing measures that reduce or eliminate the long-term risk of flood damage to buildings, homes, and other structures insurable under the NFIP. The long-term goal of FMA is to reduce or eliminate claims under the NFIP through mitigation activities.



The Biggert-Waters Flood Insurance Reform Act of 2012 eliminated the Repetitive Flood Claims (RFC) and Severe Repetitive Loss (SRL) programs and made the following significant changes to the FMA program:

- The definitions of repetitive loss and SRL properties have been modified.
- Cost-share requirements have changed to allow more federal funds for properties with RFC and SRL properties.
- There is no longer a limit on in-kind contributions for the nonfederal cost share.

One limitation of the FMA program is that it is used to provide mitigation for *structures* that are insured or located in SFHAs. Therefore, the individual property mitigation options are best suited for FMA funds. Like PDM, FMA programs are subject to the availability of appropriation funding as well as any program-specific directive or restriction made with respect to such funds.

<http://www.fema.gov/flood-mitigation-assistance-grant-program>

NYS Department of State

The Department of State may be able to fund some of the projects described in this report. In order to be eligible, a project should link water quality improvement to economic benefits.

NYS Department of Environmental Conservation – Municipal Waste Reduction and Recycling (MWRR) Program

The NYS Department of Environmental Conservation (DEC) administers MWRR funding to local government entities for waste reduction and recycling projects. The overall goal of this funding program is to assist municipalities in expanding or improving local waste reduction and recycling programs and to increase participation in those programs.

The MWRR state assistance program can help fund the costs of the following:

- Capital investment in facilities and equipment

Eligible projects are expected to enhance municipal capacity to collect, aggregate, sort, and process recyclable materials. Recycling equipment includes structures, machinery, or devices providing for the environmentally sound recovery of recyclables including source separation equipment and recyclables recovery equipment.

U.S. Army Corps of Engineers (USACE)

The USACE provides 100 percent funding for floodplain management planning and technical assistance to states and local governments under several flood control acts and the Floodplain Management Services (FPMS) Program. Specific programs used by the USACE for mitigation are listed below.

- Section 205 – Small Flood Damage Reduction Projects: This section of the 1948 Flood Control Act authorizes the USACE to study, design, and construct small flood control projects in partnership with nonfederal government agencies. Feasibility studies are 100 percent federally funded up to \$100,000, with additional costs shared equally. Costs for preparation of plans and construction are funded 65 percent with a 35 percent nonfederal match. In certain cases, the nonfederal share for construction could be as high as 50 percent. The maximum federal expenditure for any project is \$7 million.
- Section 14 – Emergency Stream Bank and Shoreline Protection: This section of the 1946 Flood Control Act authorizes the USACE to construct emergency shoreline and stream bank protection works to protect public facilities such as bridges, roads, public buildings, sewage treatment plants, water wells, and nonprofit public facilities such as churches, hospitals, and schools. Cost sharing is similar to Section 205 projects above. The maximum federal expenditure for any project is \$1.5 million.
- Section 208 – Clearing and Snagging Projects: This section of the 1954 Flood Control Act authorizes the USACE to perform channel clearing and excavation with limited embankment construction to reduce nuisance flood damages caused by debris and minor shoaling of rivers. Cost sharing is similar to Section 205 projects above. The maximum federal expenditure for any project is \$500,000.
- Section 206 – Floodplain Management Services: This section of the 1960 Flood Control Act, as amended, authorizes the USACE to provide a full range of technical services and planning guidance necessary to support effective floodplain management. General technical assistance efforts include determining the following: site-specific data on

obstructions to flood flows, flood formation, and timing; flood depths, stages, or floodwater velocities; the extent, duration, and frequency of flooding; information on natural and cultural floodplain resources; and flood loss potentials before and after the use of floodplain management measures. Types of studies conducted under FPMS include floodplain delineation, dam failure, hurricane evacuation, flood warning, floodway, flood damage reduction, stormwater management, floodproofing, and inventories of flood-prone structures. When funding is available, this work is 100 percent federally funded.

In addition, the USACE provides emergency flood assistance (under Public Law 84-99) after local and state funding has been used. This assistance can be used for both flood response and postflood response. USACE assistance is limited to the preservation of life and improved property; direct assistance to individual homeowners or businesses is not permitted. In addition, the USACE can loan or issue supplies and equipment once local sources are exhausted during emergencies.

Other Potential Sources of Funding

New York State Grants

All New York State grants are now announced on the NYS Grants Gateway. The Grants Gateway is designed to allow grant applicants to browse all NYS agency anticipated and available grant opportunities, providing a one-stop location that streamlines the way grants are administered by the State of New York.

<https://grantsmanagement.ny.gov/>

Bridge NY Program

The Bridge NY program, administered by NYSDOT, is open to all municipal owners of bridges and culverts. Projects are awarded through a competitive process and support all phases of project development. Projects selected for funding are evaluated based on the resiliency of the structure, including such factors as hydraulic vulnerability and structural resiliency; the significance and importance of the bridge including traffic volumes, detour considerations, number and types of businesses served and impacts on commerce; and the current bridge and culvert structural conditions.

<https://www.dot.ny.gov/BRIDGENY>.

Private Foundations

Private entities such as foundations are potential funding sources in many communities. Communities will need to identify the foundations that are potentially appropriate for some of the actions proposed in this report.

In addition to the funding sources listed above, other resources are available for technical assistance, planning, and information. While the following sources do not provide direct funding, they offer other services that may be useful for proposed flood mitigation projects.

Land Trust and Conservation Groups

These groups play an important role in the protection of watersheds, including forests, open space, aquatic ecosystems, and water resources.

Communities will need to work closely with potential funders to ensure that the best combinations of funds are secured for the proposed alternatives and for the property-specific mitigation such as floodproofing, elevations, and relocations. It will be advantageous for the communities to identify combinations of funding sources in order to reduce their own requirement to provide matching funds.

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