Flood Mitigation Study

Schoharie Watershed

Contract #C1000449
Tasks 7-1 through 7-4

Schoharie, Albany, Montgomery, Otsego, and Schenectady Counties, New York
April 2017

This study was prepared for the New York State Department of State and Schoharie County SWCD with funds provided under Title 11 of the Environmental Protection Fund Act

Engineering | Planning | Landscape Architecture | Environmental Science

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April 2017

Prepared for:
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ABBREVIATIONS/ACRONYMS

BIN	Bridge Identification Number
CDBG	Community Development Block Grant
CFS	Cubic Feet per Second
CSSO	Conditional Seasonal Storage Objective
DEC	Department of Environmental Conservation
DPW	Department of Public Works
EWP	Emergency Watershed Protection
FEMA	Federal Emergency Management Agency
FIRM	Flood Insurance Rate Map
FIS	Flood Insurance Study
FMA	Flood Mitigation Assistance
GIS	Geographic Information System
HEC-RAS	Hydrologic Engineering Center – *River Analysis System*
HW/D	Headwater to Culvert Depth Ratio
HWM	High Water Mark
LFA	Local Flood Analysis
LFHMA	Local Flood Hazard Mitigation Analysis
LiDAR	Light Detection and Ranging
LOMR	Letter of Map Revision
MMI	Milone & MacBroom, Inc.
NFIP	National Flood Insurance Program
NOAA	National Oceanic and Atmospheric Administration
NRCS	Natural Resources Conservation Service
NWI	National Wetland Inventory
NYCDEP	New York City Department of Environmental Protection
NYRCRP	New York Rising Community Reconstruction Plan
NYPA	New York Power Authority
NYS	New York State
NYSDEC	New York State Department of Environmental Conservation
NYSDOS	New York State Department of State
NYSDOT	New York State Department of Transportation
PDM	Pre-Disaster Mitigation
RLP	Repetitive Loss Property
SALT	Schoharie Area Long Term, Inc.
SCSWCD	Schoharie County Soil and Water Conservation District
SFHA	Special Flood Hazard Area
Sq. mi.	Square Mile
SRLP	Severe Repetitive Loss Property
T	Trout Waters
TMDL	Total Maximum Daily Load
TS	Trout Spawning
USACE	United States Army Corps of Engineers
USGS	United States Geological Survey
WQC	Water Quality Certification
WTS	Water Treatment System

EXECUTIVE SUMMARY

The Schoharie County Soil and Water Conservation District (SCSWCD) has retained Milone & MacBroom, Inc. (MMI) to complete a Flood Mitigation Study for the Lower Schoharie Creek watershed. Funding for this study has been provided from the New York State Department of State (NYSDOS) under Title 11 of the Environmental Protection Fund for the Local Waterfront Revitalization Program. The study is part of Phase 1 of the Mohawk River Watershed Management Plan Implementation.

With a watershed of approximately 930 square miles, Schoharie Creek drains the northwestern Catskill Mountains. A tributary to the Mohawk River, Schoharie Creek flows through Schoharie County from south to north. The terrain within the watershed is a mix of mountainous landscapes and flat, narrow valleys. Ground elevations range from an average of about 1,200 feet in the northern limestone plateau section of the county to approximately 2,000 feet in the higher plateaus in the southern part of Schoharie County, with the headwaters in Greene County at an elevation of 4,000 feet (Schoharie County All-Hazards Mitigation Plan, 2006).

The Schoharie basin has a long and destructive history of flooding, including most recently as a result of Tropical Storms Irene and Lee.

The Schoharie Creek basin is particularly prone to flooding due to a number of factors, including the location of the headwaters in the Catskill Mountains; the low permeability of the mountainous landscape; the lack of wetland habitats or lakes within the watershed to retain stormwaters; and the prevalent winds, which during coastal storms push storm air masses up and over the mountains, causing cooling and subsequently high amounts of precipitation. As the wettest region in New York State with over 60 inches of precipitation annually, individual rainfall events of 5 inches are common. These and other factors contribute to the flash flood conditions within the basin.

The Schoharie basin has a long and destructive history of flooding, including most recently as a result of Tropical Storms Irene and Lee. By far the largest storm on record occurred on August 28, 2011, as Tropical Storm Irene dumped up to 14 inches of rain within the Schoharie basin, resulting in a peak flow rate in Schoharie Creek of 128,000 cubic feet per second (cfs). This catastrophic flooding was followed by additional precipitation on September 7, 2011, as Tropical Storm Lee dropped a reported 2 to 7 inches of additional rain. Flows in Schoharie Creek exceeded the predicted 500-year flood in some locations, resulting in well over $100 million in estimated damages.

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Public input has been a key element of this study. At the onset of investigations, the public was engaged in an effort to: (1) inform them about the Schoharie flood study, its goals, and intended outcomes; and (2) gather information on floodprone areas and flooding problems. Public meeting attendance and individual participation were excellent. A dialogue was also sought with County Soil and Water District staff in the Schoharie, Otsego, Montgomery, Schenectady, and Albany Counties as well as representatives of various towns, villages, and state agencies.

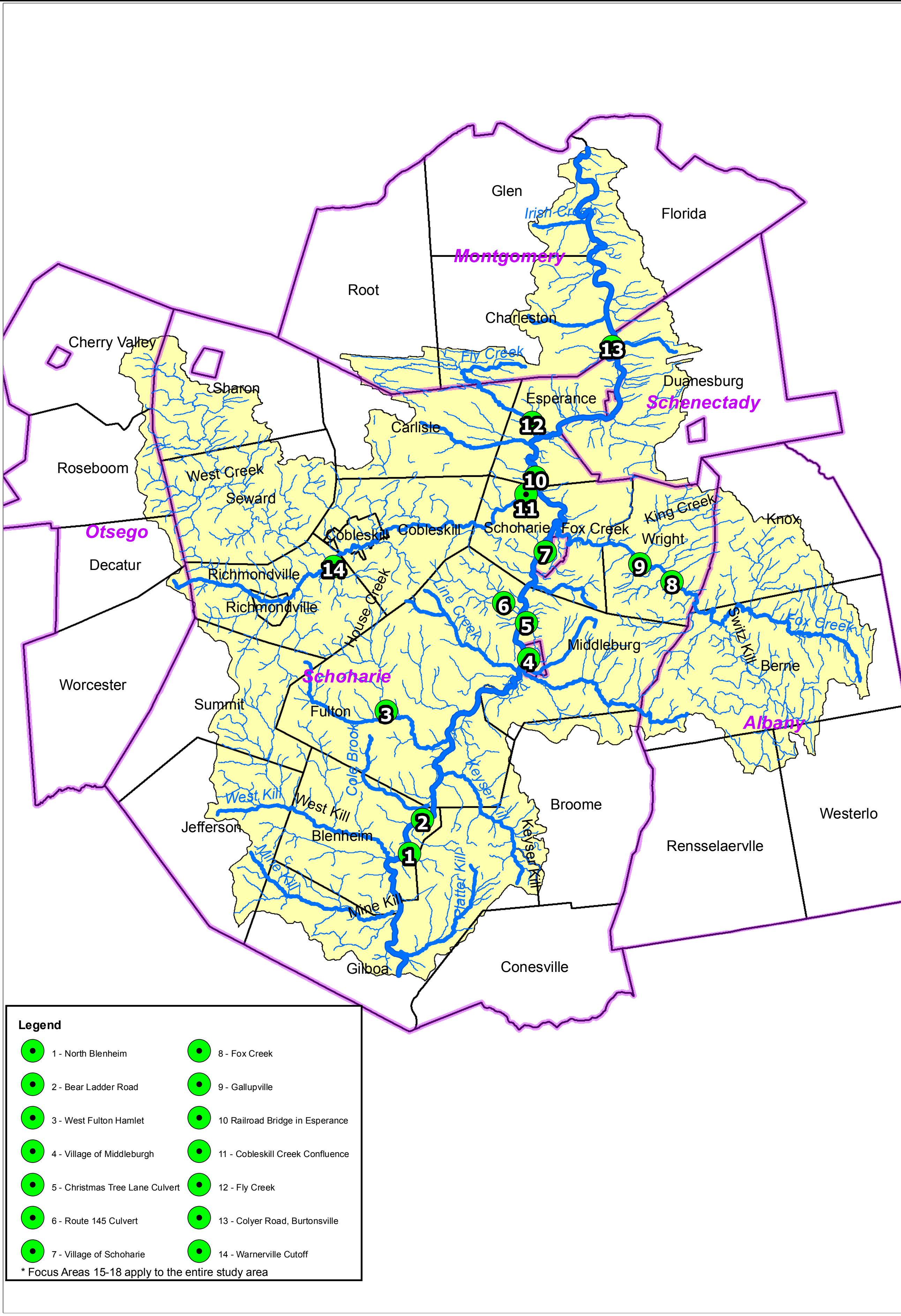
For the purposes of this assessment, 18 focus areas were identified within the Lower Schoharie Creek watershed. Fifteen of the focus areas are specific locations while the remaining three areas can be applied throughout the watershed. A greater level of information was collected for the focus areas in order to assess potential flood mitigation projects. Within each focus area, MMI staff conducted on-the-ground assessments and visual inspections, including identification of land uses and low-lying structures, assessment of bank and channel conditions, measurements of valley confinement, measurements of bridge and culvert openings, and assessment of vegetation along the stream corridors. For each focus area, a range of flood mitigation alternatives was developed and evaluated, and hydraulic modeling was conducted where appropriate. Alternatives were recommended for those alternatives that were found to provide substantial flood mitigation benefit at a cost that would justify their implementation.

Eighteen flood mitigation focus areas were identified within the Lower Schoharie Creek watershed. Fifteen are location specific; three apply to the entire watershed.

The 18 focus areas are listed in Table ES-1 and are graphically depicted in Figure ES-1. A summary discussion follows.

TABLE ES-1
Summary of Floodprone Focus Areas

Focus Area #	*Reference Name*
1	North Blenheim
2	Bear Ladder Road
3	West Fulton Hamlet
4	Village of Middleburgh
5	Christmas Tree Lane Culvert
6	Route 145 Culvert
7	Village of Schoharie
8	Fox Creek
9	Gallupville
10	Railroad Bridge in Esperance
11	Cobleskill Creek Confluence
12	Fly Creek
13	Colyer Road, Burtonsville
14	Warnerville Cutoff
15	Flood Attenuation in Upper Watershed
16	Berms along Farm Fields
17	Flood Attenuation in Reservoirs
18	Protection of Wetlands, Floodplains, and Green Infrastructure



SOURCE(S):
USGS StreamStats Version 3.0 (04/2016)
USGS National Hydrography Dataset (04/2016)
NYS GIS Clearinghouse (04/2016)

Figure ES-1: Focus Areas within Schoharie Creek Project Basin

Location: Schoharie Creek Watershed, NY

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Schoharie Creek Flood Study

Map By: EMH
MMI#: 4805-05
MXD: Q:\Projects\4805-05 Schoharie Basin Flood Analysis\GIS\MDX\Focus Area Points 9272106.mxd
1st Version: 04/25/2016
Revision: 9/30/2016
Scale: 1 in = 31,970 ft

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Focus Area #1 – North Blenheim

Focus Area #1 includes an approximately 1.5-mile reach of Schoharie Creek as it flows through the hamlet of North Blenheim. The creek flows across a section of bedrock channel as it approaches the hamlet. As it flows past North Blenheim and under the New York State (NYS) Route 30 bridge, Schoharie Creek is somewhat confined within its river valley, making contact with the right valley wall just downstream of the bridge where the creek runs parallel to NYS Route 30. The hamlet was severely damaged by flooding during Tropical Storm Irene. The following flood mitigation alternatives were evaluated for this focus area:

- Alternative 1-1: Replacement of Historic Covered Bridge
- Alternative 1-2: Floodplain Enhancement
- Alternative 1-3: Sediment Removal

The following recommendations are offered:

1. <u>Alternative 1-2c Floodplain Enhancement</u> – Floodplain enhancement and sediment removal scenario as described in Alternative 1-2c is recommended. This scenario was found to be effective at lowering water surface elevations by up to 2 feet over a distance of two-thirds of a mile upstream, which includes the North Blenheim hamlet. Many structures would be removed from the Federal Emergency Management Agency (FEMA) Special Flood Hazard Area (SFHA) while those that would remain in the SFHA would see reductions in flood elevations. The construction of this enhancement and sediment removal scenario would impact approximately 1,100 linear feet of Schoharie Creek and would require the removal of approximately 20,000 cubic yards of material. Engineering design and permitting are anticipated on the order of $68,000 while construction would be anticipated on the order of $820,000. This estimate does not include the cost of any land acquisition or construction easements that may be required or the relocation of utilities.

2. <u>Alternative 1-1 – Replacement of Covered Bridge</u> – If the Blenheim Covered Bridge is to be replaced, the replacement deck should be set at an elevation that is 10 feet higher than the deck of the former historic bridge. The replacement bridge should be set on the existing abutments or on new abutments that do not occupy more space in the channel than the existing abutments, and no roadway embankment should be constructed on the left side of the bridge to connect the bridge deck to the left bank. Hydraulic modeling should be conducted as part of the engineering design to ensure that the new bridge does not cause an increase in water surface elevations. It is also recommended that a Letter of Map Revision (LOMR) be prepared that reflects the current condition in North Blenheim either with no covered bridge or with a new bridge at a higher elevation.

Focus Area #2 – Bear Ladder Road

Focus Area #2 is located where Bear Ladder Road (County Route 31) parallels Schoharie Creek, just north of the hamlet of North Blenheim. Frequent flooding is reported at a location approximately 2 miles downstream of the NYS Route 30 bridge coincident with a low spot in the road. When the area floods, travel becomes unsafe or impossible, and access is cut off to several residences. The following alternatives were evaluated within this focus area:

- Alternative 2-1: Floodplain Modification
- Alternative 2-2: Raise Roadway
- Alternative 2-3: Roadway Signage and Closure

Neither floodplain modification nor raising the long stretch of Bear Ladder Road through this reach was found to result in significant flood mitigation. Instead, immediate closure of Bear Ladder Road during flooding conditions is recommended, with effective signage and further consideration of alternative routes as described in Alternative 2-3.

Focus Area #3 – West Fulton Hamlet

Focus Area #3 is located in the hamlet of West Fulton and includes House Creek and Panther Creek, both of which are tributaries to Schoharie Creek. Two vehicular bridges located in the hamlet of West Fulton, about 600 feet apart, have been identified as being prone to debris jams and overtopping during flood events: the Patria Road bridge over House Creek and the West Fulton Road (County Route 4) bridge over Panther Creek. The following alternatives were evaluated within this focus area:

- Alternative 3-1: Replace Patria Road Bridge over House Creek
- Alternative 3-2: Replace West Fulton Road Bridge over Panther Creek
- Alternative 3-3: Create Compound Channel with Floodplain along Panther Creek

The following recommendations are offered:

1. Alternatives 3-2 and 3-3 – Bridge Replacement and Compound Channel at West Fulton Road – This bridge is undersized, as is the upstream channel, and thus inadequate for conveyance of flood flows and debris. When the bridge is slated for replacement, the structure should be widened to improve debris movement and conveyance of flood flows.

2. Alternative 3-1 – Bridge Replacement at Patria Road – Near-term bridge replacement is not likely warranted; however, when the Patria Road bridge is slated for replacement, the structure should be widened to improve debris movement and conveyance of flood flows.

Focus Area #4 – Village of Middleburgh

Schoharie Creek flows across a wide, flat-bottomed valley with an extensive floodplain as it approaches and flows past the town of Middleburgh between Route 30 and Route 145. In some locations, the floodplain is over a mile wide. Many buildings along River Street in Middleburgh are located within the 100-year floodplain. The following alternatives were evaluated within this focus area:

- Alternative 4-1: Modify/Replace the NYS Route 30 Bridge
- Alternative 4-2: Floodplain Enhancement
- Alternative 4-3: Right Bank Floodplain Enhancement
- Alternative 4-4: Dredging
- Alternatives 4-5a and 4-5b: Flood Control Levee and Wall
- Alternative 4-6: Individual Building Floodproofing

Replacement of the NYS Route 30 bridge with a wider or taller structure (Alternative 4-1) *would not* reduce flooding at nearby buildings. Given the broad, flat nature of the Schoharie Creek floodplain in this area and the fact that the adjacent floodplain is already quite frequently flooded, little flow capacity is predicted to be gained and little flood reduction benefit as a result of floodplain enhancement (Alternatives 4-2 and 4-3). Hydraulic modeling predicts that channel dredging (Alternative 4-5) would provide only minimal flood reduction benefit, with a cost on the order of $2.3M.

Flood control levees and walls (Alternatives 4-5a and 4-5b) would require a considerable amount of private property acquisition and considerable maintenance, with costs in the $4M to $5M range or greater. A risk associated with these scenarios is the danger of a flood event that exceeds the design storm and overtops or breaches the levee or floodwall and is then trapped. In Middleburgh, peak flows in Schoharie Creek during Tropical Storm Irene exceeded the predicted 100-year storm event. Under such a scenario, it is possible that floodwaters from the creek would have overtopped a levee or floodwall designed to protect structures and properties. Once a levee has been overtopped, floodwaters can become trapped behind it, thus exacerbating flooding problems.

Given the shortfalls of the construction alternatives, individual floodproofing or relocation (Alterative 4-6) is recommended for floodprone areas in Middleburgh. A range of measures is available to protect existing public and private properties from flood damage. On a case-by-case basis where structures are at risk, individual floodproofing should be explored.

Focus Area #5 – Christmas Tree Lane Culvert

Focus Area #5 is located in the town of Middleburgh just south of Christmas Tree Lane. A culvert that traverses NYS Route 30 and conveys a small unnamed tributary to Schoharie Creek is reported to overtop frequently. The following alternatives were evaluated within this focus area:

- Alternative 5-1: Increase Culvert Capacity
- Alternative 5-2: Raise Roadway
- Alternative 5-3: Relocate Roadway
- Alternative 5-4: Roadway Signage and Closure

Replacement of the small culvert under NYS Route 30 (Alternative 5-1) was evaluated and found not to be a large contributor to flooding along the roadway and is not recommended. Due to the high cost of Alternatives 5-2 and 5-3 in relation to the mitigation benefit offered, neither is recommended. Closure of NYS Route 30 during flooding conditions, along with effective signage and further consideration of alternative routes, would provide a low-cost alternative and is recommended for implementation.

Focus Area #6 – Route 145 Culvert in Middleburgh

A concrete box culvert is located at the crossing of NYS Route 145 over an unnamed tributary to Schoharie Creek in the town of Middleburgh. The culvert is reportedly undersized, floods frequently, and is prone to debris jams. The following alternatives were evaluated within this focus area:

- Alternative 6-1: Replace Culvert
- Alternative 6-2: Program of Debris Management

The following recommendations are offered for Focus Area #6 in order of priority:

1. Alternative 6-2 – Debris Management – The development of a debris management program would reduce the volume of upstream debris being mobilized and delivered to the culvert and is recommended for immediate implementation.

2. Alternative 6-1 – Route 145 Culvert Replacement – As a first step, confirmation should be obtained from the New York State Department of Transportation (NYSDOT), Schoharie County Department of Public Works (DPW), or local highway superintendents as to the frequency of flooding associated with this culvert. If the culvert has a history of flooding, scour, and/or clogging, it is recommended that the culvert be replaced with a larger structure that can adequately pass the 50- or 100-year flood event with acceptable headwater to culvert depth (HW/D) ratio requirements.

Focus Area #7 – Village of Schoharie

The village of Schoharie is located in Schoharie County, the county seat. Schoharie Creek flows west of the village and under the Bridge Street bridge. Schoharie Creek flows across a wide, flat-bottomed valley with an extensive floodplain as it flows past the village of Schoharie. According to the FEMA Flood Insurance Rate Maps (FIRMs), the village of Schoharie along Main Street is subject to inundation during the 100-year flood event. The expansive flood zone associated with the 100-year flood event extends into the village of Schoharie, inundating portions of Main Street and affecting neighborhoods to the west of Main Street and portions of the village to the east of Main Street. Four flood mitigation alternatives were evaluated for the Schoharie focus area:

- Alternative 7-1: Floodplain Enhancement
- Alternative 7-2: Dredging
- Alternatives 7-3a and 7-3b: Levee Scenarios
- Alternative 7-4: Individual Building Floodproofing

The floodplain enhancement and dredging scenarios were found to have a minimal benefit toward the reduction of floodwater elevations and at a very high cost. Both levee scenarios while preventing flooding in key areas would be very costly, would be disruptive to the community, would require long-term maintenance, and would not completely remove the community from risk.

The recommended flood mitigation alternative in the village of Schoharie is the relocation and floodproofing of individual structures (Alternative 7-4). A range of measures is available to protect existing public and private properties from flood damage. On a case-by-case basis where structures are at risk, individual floodproofing should be explored.

Focus Area #8 – Fox Creek

Focus Area #8 includes an approximately 3.5-mile-long reach of Fox Creek beginning downstream of the County Route 9 bridge in the hamlet of West Berne, town of Berne, in Albany County and extending downstream to the NYS Route 443 crossing in Schoharie County. This section of Fox Creek runs along or crosses Route 443 for its entire length and passes under a total of six bridges. This section of Fox Creek has been flooding and is prone to sediment aggradation and debris jams, especially at the bridges. The following alternatives were evaluated within this focus area:

- Alternate 8-1: Modification/Replacement of the NYS Route 443 Bridge (Upper)
- Alternate 8-2: Modification/Replacement of the Schell Road Bridge
- Alternate 8-3: Modification/Replacement of Schoonmaker Road Bridge
- Alternate 8-4: Modification/Replacement of Zimmer Road Bridge
- Alternative 8-5: Modification/Replacement of Sholtes Road Bridge
- Alternative 8-6: Modification/Replacement of NYS Route 443 Bridge (Lower)
- Alternative 8-7: Sediment Management
- Alternative 8-8: Bank Erosion Repairs

The following recommendations are offered for this focus area:

1. Sediment Management – The development of a sediment management plan (Alternative 8-7) is recommended for Fox Creek with a focus on stabilization of banks and high bank failures (Alternative 8-8) within and upstream of this focus area.

2. Bridge Replacement – It is recommended that the Zimmer Road bridge (Alternative 8-4) and the Sholtes Road bridge (Alternative 8-5) be replaced with structures that can safely pass the 100-year flood event with adequate freeboard and with a span that is at least 1.25 times the bankfull width of the channel. An approximate cost of replacing the Sholtes Road and Zimmer Road bridges is $1.4M to $1.8M per bridge for construction.

   The two bridges that carry NYS Route 443 over Fox Creek (Alternatives 8-1 and 8-6) span the bankfull width of the channel and are capable of passing the 50-year flood. At the more downstream of the two bridges, floodwaters overtop the roadway adjacent to the bridge in the 50-year flood event. These bridges are not recommended for immediate replacement; however, when the downstream bridge is scheduled for replacement, its replacement should span the floodplain.

   When the Schoonmaker Road bridge is due for replacement, it should be replaced with a structure that can safely pass the 100-year flood event with adequate freeboard and is at least 130 feet in width.

3. Abutment Alteration – The Schell Road bridge is not recommended for immediate replacement; however, it may be feasible to remove the remnants of the center pier and remove or modify the old left abutment, which would increase the hydraulic capacity of the bridge and make it less susceptible to debris jams.

Focus Area #9 – Gallupville

The hamlet of Gallupville, through which Fox Creek runs, was subjected to flooding during Tropical Storm Irene. The flooding was most severe along School Street, Mill Street, and Factory Street, especially in the area of the public works garage and firehouse. The following three alternatives were evaluated within this focus area:

- Alternative 9-1: Modification/Replacement of the School Street Bridge
- Alternative 9-2: Floodplain Enhancement
- Alternative 9-3: Individual Building Relocation, Elevation, or Floodproofing

The School Street bridge (Alternative 9-1) was not found to act as a hydraulic constriction. Floodplain enhancement (Alternative 9-2) did not result in a substantial reduction in flood levels. Given the limited opportunities in this focus area, it is recommended that individual, frequently flooded buildings within the hamlet be assessed for elevation, relocation, or floodproofing, especially in the area of the public works garage and along Factory Street. Structures should be assessed on a case by case basis, depending on owner interest, type of building, and frequency of flood damages.

Focus Area #10 – Railroad Bridge in Esperance

In the town of Esperance, Schoharie Creek flows under an active Canadian Pacific Rail railroad bridge, which crosses the floodplain and spans the creek. In total, the railroad embankment and two bridges cross approximately 2,500 feet, or nearly half a mile of floodplain. FEMA FIRMs indicate that an extensive area upstream of the railroad bridge, including agricultural fields, the neighborhoods along Junction Road and Beechnut Lane, and the Junction Road roadway itself, is subject to inundation during the 100-year flood event. The neighborhood on Beechnut Lane was inundated during Tropical Storm Irene, with damage to properties and structures. Many of the structures in this area were destroyed and have not been rebuilt. The following alternatives were evaluated within this focus area:

- Alternative 10-1: Modification/Replacement of Canadian Pacific Railroad Bridge
- Alternative 10-2: Compliance with and Enforcement of National Flood Insurance Program (NFIP)

In order to eliminate the hydraulic constriction caused by the rail crossing, the bridges and the railroad embankment would need to be removed from the floodplain. Removal of an active Canadian Pacific railroad line over Schoharie Creek is unlikely. If use of the rail line were to be discontinued in the future, the removal of the railroad line from the floodplain should be investigated. In the meantime, individual building floodproofing is recommended, along with stringent requirements on any future development in the floodplain.

Focus Area #11 – Cobleskill Creek Confluence

This study area focuses on the lower reach of Cobleskill Creek just upstream of its confluence with Schoharie Creek in the town of Central Bridge, Schoharie County. NYS Route 30A serves as an important route out of this floodprone area of the Schoharie Valley during large flood events. During Tropical Storm Irene, water overtopped the NYS Route 30A roadway in the area just north of the bridge, making the road impassible. This section of the creek is subject to sediment aggradation and bank erosion. The following alternatives were evaluated:

- Alternative 11-1: Modify/Replace Church Street Bridge
- Alternative 11-2: Modify/Replace NYS Route 30A Bridge and Roadway
- Alternative 11-3: Individual Building Relocation, Elevation, or Floodproofing
- Alternative 11-4: Roadway Signage and Closure

The following recommendations are offered:

1. Alternative 11-3 – Individual Floodproofing – The relocation of structures and greenhouses located just downstream of Church Street is recommended as well as preventing development in the floodway and requiring that any new construction meet NFIP criteria.

2. Alternative 11-4 – Road Closure – Closure of the floodprone section of Route 30A during flooding events is recommended in combination with the installation of effective barriers and clear signage to direct travelers to alternative routes.

Focus Area #12 – Fly Creek

This focus area begins at the Fly Creek and Schoharie Creek confluence adjacent to the Junction Road bridge and extends upstream along Fly Creek for approximately 1.5 miles upstream of the Route 20 bridge in the hamlet of Sloansville, Town of Esperance. The FEMA FIRM indicates locations that experience inundation under different flooding scenarios. Although flooding is a problem along Fly Creek, the larger, related issues are bank erosion, sediment aggradation, and channel instability. The following alternatives were evaluated within this focus area:

- Alternative 12-1: SCSWCD Natural Channel Design Scenario #1
- Alternative 12-2: SCSWCD Natural Channel Design Scenario #2
- Alternative 12-3: Sediment Management Plan

Bank erosion, sediment aggradation, and channel instability are problematic along Fly Creek. The natural setting makes this section of the creek very prone to sediment aggradation and channel instability while repeated dredging has contributed to this channel instability. Restoration actions will be required to stabilize the failing banks, reduce bank erosion, and prevent damage to homes and buildings located close to the eroding stream banks. It is recommended that the SCSWCD plans be developed to a more advanced design stage and that restoration actions be undertaken at Fly Creek. Of the two scenarios, SCSWCD Natural Channel Design Scenario #2 (Alternative 12-2) most closely aligns with the goals for Fly Creek and is recommended.

Because sediment aggradation will continue to occur along Fly Creek, it is recommended that a sediment management plan be developed for Fly Creek (Alternative 12-3).

Focus Area #13 – Colyer Road, Burtonsville

This focus area includes a reach of Schoharie Creek where it runs along the Schoharie County/ Montgomery County line. Colyer Road is located along the left bank of Schoharie Creek in the hamlet of Burtonsville, town of Charleston, in Montgomery County. The reach is just upstream of where Bramans Corner Road (County Route 160) crosses over Schoharie Creek. Extensive flooding of homes occurred along Colyer Road during Tropical Storm Irene. Based on a review of aerial photographs, homes that were once located along the east side of Colyer Road have been removed since the occurrence of Tropical Storm Irene, presumably as a result of damages sustained during the flood. The following alternatives were evaluated within this focus area:

- Alternative 13-1: Modification or Enhancement of Channel or Floodplain
- Alternative 13-2: Survey, Followed by Individual Building Relocation, Elevation, or Floodproofing

Alterations to the channel at this location (Alternative 13-1) would be difficult and costly to undertake due to the presence of bedrock in the channel bed, the high embankment along the right bank, and the close proximity of the homes along Colyer Road to the channel. Survey of first-floor elevations (Alternative 13-2) would allow residents to decide on a case-by-case basis whether building elevation or property acquisition and demolition with relocation to a safe location outside of the floodplain would be most beneficial.

Focus Area #14 – Warnerville Cutoff

Warnerville Cutoff (County Route 23A) is a roadway that crosses over Cobleskill Creek in the hamlet of Warnerville, town of Richmondville, in Schoharie County. Warnerville Cutoff intersects with NYS Route 7/10 in Warnerville center. West Creek flows parallel to Warnerville Cutoff and crosses under it before flowing into Cobleskill Creek approximately 500 feet downstream of the Warnerville Cutoff bridge over Cobleskill Creek. A low area of Warnerville Cutoff, located approximately 400 feet to the northwest of the bridge over Cobleskill Creek, floods on a frequent basis. The following alternatives were evaluated within this focus area:

- Alternative 14-1: Elevation of the Roadway along Warnerville Cutoff
- Alternative 14-2: Elevation of Roadway and Installation of Bypass Culvert under Warnerville Cutoff
- Alternative 14-3: Elevation of Roadway and Installation of Bypass Bridge along Warnerville Cutoff
- Alternative 14-4: Warnerville Cutoff Roadway Signage and Closure

Alternatives 14-1, 14-2, and 14-3 are not recommended because they would not prevent flooding of Warnerville Cutoff and would cause an increase in water surface elevations upstream of the Warnerville Cutoff bridge over Cobleskill Creek and increase flooding risk in the area of the Warnerville Post Office. Immediate closure of Warnerville Cutoff during flooding conditions, effective signage, and further consideration of alternative routes is recommended (Alternative 14-4).

Focus Area #15 – Review of Potential for Flood Attenuation in Upper Watershed

Several comments were received during the public meeting session suggesting that floodwaters could be stored in existing lakes, ponds, or wetlands in order to attenuate downstream flood flows. Two sites within the Schoharie Creek watershed were investigated for their potential to reduce peak flows during storm events by storing a portion of the floodwater. The sites are located at two lakes along tributaries to Fox Creek – Warner Lake and Onderdonk Lake. The following alternatives were evaluated within this focus area:

- Alternative 15-1: Potential for Flood Storage at Warner Lake
- Alternative 15-2: Potential for Flood Storage at Onderdonk Lake
- Alternative 15-3: Potential for Flood Storage at Other Lakes, Ponds, and Wetlands

Stormwater storage at small lakes and ponds in the watershed does benefit downstream property owners by reducing peak flows. However, the potential to further increase storage at these sites is relatively small and is not recommended. 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.

Focus Area #16 – General Review of Berms along Farm Fields

During the data gathering stage for this flood study, interest was expressed in determining what effect, if any, agricultural berms along Schoharie Creek have on downstream flood flows. While a comprehensive inventory of the berms is beyond the scope of the study, an evaluation was made of the berms at two locations:

- Alternative 16-1: Agricultural Berm Site 1
- Alternative 16-2: Agricultural Berm Site 2

These agricultural berms were evaluated for potential removal and were found to have only a minor influence on downstream peak flows. However, berms and levees can influence flow velocities and water depths in cases where they confine the channel and isolate portions of the floodplain. In cases along Schoharie Creek where berms are not protecting important lands or infrastructure, it is recommended that their removal be undertaken.

Focus Area #17 – Review of Potential for Flood Attenuation

During the data gathering process and public input at the onset of this flood study, there was interest in determining the influence that upstream reservoirs may have had on the volume of flood flows experienced along Schoharie Creek during Tropical Storm Irene. Potential for flood storage was evaluated in Schoharie Reservoir and in the Blenheim-Gilboa Reservoir. Additionally, three large flood control dams are maintained in the upper Schoharie Creek Watershed within the Batavia Kill subwatershed. They were constructed by the U.S. Department of Agriculture Natural Resources Conservation Service (NRCS) following a 1960 flood. The pools created by the earthen dams normally contain little water, providing "void" space that is used to temporarily detain floodwater.

Reservoir storage during Tropical Storm Irene mitigated a moderate to substantial amount of downstream flooding. Storage in Schoharie Reservoir resulted in a reduction in peak flows of nearly 20 percent. Measures currently being implemented by the New York City Department of Environmental Protection (NYCDEP) will result in the potential for additional peak flow attenuation. Storage in the Blenheim-Gilboa Reservoir reduced peak flows by 8.1 percent. Neither reservoir is designed to operate in a flood control capacity. Flood control dams located in the upper Schoharie Creek Watershed, on the Batavia Kill, performed as designed and further reduced peak flows.

Focus Area #18 – Protection of Wetlands, Floodplains, and Green Infrastructure

An additional consideration to mitigate flood damages is to maintain the overall health of the watershed since watersheds naturally cycle, filter, and store water. Water enters the watershed as rain, which soaks into the ground, fills ponds and wetlands, and trickles into small intermittent streams that run into larger streams and finally rivers. The watershed stores water, moves it along, or transfers it underground to replenish groundwater. Land development activities change the surface of the land in the watershed by adding impervious surfaces, filling small wetlands, and rerouting streams. These activities change the path of water and ultimately influence where water goes during heavy storms.

Additional recommendations to reduce damages and maintain flood resiliency in the Schoharie Creek watershed are listed below:

Green Infrastructure Recommendations

- Reroute downspout water to rain barrels, cisterns, or permeable areas that allow it to soak into the soil.
- Create rain gardens that collect and absorb stormwater runoff.
- Create and maintain vegetated channels that collect, slow, and filter stormwater and allow it to soak into the soil.
- Install permeable pavements that intercept rainwater, allowing it to infiltrate into the soil.
- Use permeable pavement, trees, rain gardens, and bioswales in and adjacent to parking areas.

Vegetated Buffers Recommendations

- Protect existing buffers from removal, damage, major disturbance, and contamination. Consider local policies, zoning overlays, or buffer protection regulations.
- Prioritize the restoration and maintenance of buffers between the water and adjacent intensive land use areas.
- Keep construction, heavy equipment, and impervious surfaces out of the 100-foot buffer area to retain full benefits from the buffer.
- Establish vegetated buffers where there are none and replenish or replace vegetation to maximize buffer effectiveness. For planting plans, consult with local cooperative extension and regional Department of Environmental Conservation (DEC) offices. Maintain all three layers of vegetation wherever possible: trees, shrubs, herbaceous plants/unmowed grasses.
- Plant trees and shrubs for maximum soil stability and shade over the water.
- Use native plants to maximize sustainability of plantings and reduce cost of maintenance.
- Remove and replace invasive plants with care; contact your regional DEC office for information about management plans that minimize or avoid use of herbicides.
- Avoid mowing to the edge of the water. Mowed lawn does not provide the benefits that we receive from well-vegetated buffers but instead increases the amount of runoff and reduces groundwater recharge.

Recommendations for Protecting Forests and Open Space

- Develop a watershedwide Forest Protection Plan that encourages tree planting, directs development away from forested areas, reduces paved surfaces, and limits clearcutting or tree clearing in sensitive riparian areas.
- Encourage conservation easements that protect forested land from being developed.
- Enhance or restore the health, condition, and function of forest fragments in developed areas, improving conditions for tree growth to ensure long-term sustainability.
- Plant trees and shrubs in buffers along streams wherever feasible, focusing on reaches that are prone to erosion and flooding.
- Develop specific guidelines to limit impervious surfaces.
- Initiatives can be developed for subbasins with less than 10 percent impervious cover to keep this percent low.
- Policies can be developed for subbasins with impervious cover that approaches 10 percent to keep these areas below the threshold.

- Impervious surfaces can be reduced or replaced where possible in subbasins that are 10 percent or more impervious cover, and green infrastructure practices can be employed to mitigate impacts.
- In large subbasins, apply these recommendations to the smaller basins drained by local streams and wetlands.

Recommendations for Floodplains

- Adopt a Floodplain Management Plan for the entire watershed (consistent for all municipalities in the watershed) that may include floodplain ordinances, overlay zones, and guidelines for managing specific sites that are prone to flooding.
- Maintain unimpeded connection between a stream or river and its floodplain to improve floodwater retention and accommodation during floods.
- Use green infrastructure and best management practices within floodplains to improve existing conditions where structures are already present and reduce the extent of impervious surfaces within floodplains.

Recommendations for Streams and Wetlands

- Develop and implement a watershedwide Aquatic Buffer Ordinance or Water Resources Protection Plan that includes specific guidelines for the size and vegetative composition of buffers along all stream, lake, and wetland edges.
- Develop an inventory of "target" riparian areas for restoration to protect water quality, reduce flood damages, and provide habitat.
- Maintain natural stream channels and banks; avoid deepening or straightening channels.
- Use u-shaped rather than v-shaped runoff ditches along roads to decrease erosion and slow the water's flow.
- If there is uncertainty regarding whether a wetland is present in a particular location, have the site evaluated by a professional wetland delineator. Contact the County Soil and Water Districts for assistance.
- Avoid dumping trash and other debris (including organic debris and yard waste) in wetlands and streams.

General and Individual Property Flood Mitigation Recommendations

A number of risk areas within the Lower Schoharie Creek watershed are prone to flooding during severe rain events and associated high discharges in Schoharie Creek and its tributaries. Numerous flood mitigation alternatives have been developed and assessed in areas where flooding is known to have caused extensive damage to homes and properties. Alternatives have been evaluated through the use of hydraulic modeling.

Flood mitigation recommendations are provided that can be applied globally across the Lower Schoharie Creek watershed. In addition, more detailed analysis was conducted within 18 focus areas within the Lower Schoharie Creek watershed. A greater level of information was collected for these focus areas in order to assess potential flood mitigation projects. The following flood mitigation recommendations are provided for the Lower Schoharie Creek watershed:

Flood Preparedness – Home and business owners throughout the watershed can minimize flood damages and ensure personal safety by following the flood preparedness guidelines provided by the NFIP. The NFIP guidelines provide preparedness steps for before, during, and after a flood. Residents throughout the basin should sign up for their county's emergency notification system, which provides notifications to affected residents in the event of an emergency such as a flood. In each of the counties, residents can receive information by way of an emergency notification system.

Sediment Management – Local representatives often report a sentiment that dredging will alleviate flooding within the Lower Schoharie Creek watershed and should be pursued. In fact, in many cases dredging does little or nothing to reduce flooding and under some circumstances can lead to channel instability or overwidening, which can make flooding and sediment aggradation issues worse. The need for dredging can be reduced by reducing the sediment load at its source, by improving bed and bank stability, and by improving sediment transport through reaches that are vulnerable to deposition. In cases where sediment excavation in the stream channel is necessary, a sediment management plan or approach should be developed that would allow for proper channel sizing and slope. A sound sediment management program sets forth standards to delineate how, when, and to what dimensions sediment excavation should be performed. All necessary regulatory approvals must be obtained before sediment removal can take place.

Elevation of Structures – Elevation of a building above the level of flooding can be an effective way to reduce flood damages and is recommended where appropriate. Elevation of a house 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 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 at an elevation no less than 1 foot above the base flood elevation.

Individual Property Protection – A variety of measures are available to protect existing public and private properties from flood damage, including construction of barriers, floodwalls, and earthen berms; dry or wet floodproofing, and utility modifications within the structure. 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, it is recommended that individual floodproofing be explored.

Acquisition of Floodprone Properties – Undertaking flood mitigation alternatives that reduce the extent and severity of flooding is generally preferable to property acquisition. However, it is recognized that flood mitigation initiatives can be costly and may take years or even decades to implement. Where properties are located within the FEMA-designated flood zone and are repeatedly subject to flooding damages, strategic acquisition, either through a FEMA buyout or other governmental programs, may be a viable alternative. Such properties could be converted to passive, nonintensive land uses.

Individual Property Flood Protection – On a case-by-case basis where homes and businesses are at risk due to flooding, individual floodproofing should be explored. Property owners within FEMA-delineated floodplains should be encouraged to purchase flood insurance under the NFIP and to make claims when damage occurs.

Road Closures – Risks associated with the flooding of roadways can be reduced by temporarily closing roads during flooding events. This requires effective signage, road closure barriers, and consideration of alternative routes. Roadway closure scenarios are investigated for several of the focus areas.

Stream Gauging Improvements – The installation of permanent stream gauging stations along floodprone tributaries to Schoharie Creek is recommended. There are currently no stream gauges on many of the Schoharie Creek tributaries, making early warning systems difficult to implement.

Table ES-2 presents a summary of recommended alternatives.

TABLE ES-2
Summary of Alternatives

Alternative	Recommended for Implementation?
Focus Area #1 – North Blenheim	
Alternative 1-1: Analysis of Historic Covered Bridge	M
Alternative 1-2a: Floodplain Enhancement	N
Alternative 1-2b: Floodplain Enhancement	N
Alternative 1-2c: Floodplain Enhancement	Y
Alternative 1-3: Sediment Removal	N
Focus Area #2 – Bear Ladder Road	
Alternative 2-1: Floodplain Modifications	N
Alternative 2-2: Raise Roadway	N
Alternative 2-3: Roadway Signage and Closure	Y
Focus Area #3 – West Fulton Hamlet	
Alternative 3-1: Replace Patria Road Bridge over House Creek	In future
Alternative 3-2: Replace West Fulton Road Bridge over Panther Creek	In future
Alternative 3-3: Create Compound Channel with Floodplain along Panther Creek	Y
Focus Area #4– Village of Middleburgh	
Alternative 4-1: Modify/Replace NYS Route 30 Bridge	N
Alternative 4-2: Floodplain Enhancement	N
Alternative 4-3: Right Bank Floodplain Enhancement	N
Alternative 4-4: Dredging	N
Alternatives 4-5a and 4-5b: Flood Control Levee and Wall	N
Alternative 4-6: Individual Building Relocation, Elevation, Floodproofing	Y
Focus Area #5 – Christmas Tree Lane Culvert	
Alternative 5-1: Increase Culvert Capacity	N
Alternative 5-2: Raise Roadway	N
Alternative 5-3: Relocate Roadway	N
Alternative 5-4: NYS Route 30 Roadway Signage and Closure	Y
Focus Area #6 – Route 145 Culvert	
Alternative 6-1: Replace Culvert	M
Alternative 6-2: Program of Debris Management	Y
Focus Area #7 – Village of Schoharie	
Alternative 7-1: Floodplain Enhancement	N
Alternative 7-2: Dredging	N
Alternatives 7-3a and 7-3b: Levee Scenarios	N
Alternative 7-4: Individual Building Relocation, Elevation, Floodproofing	Y
Focus Area #8 – Fox Creek	
Alternative 8-1: Modification/Replacement of the NYS Route 443 Bridge (Upper)	N
Alternative 8-2: Modification/Removal of Abutments at Schell Road Bridge	M
Alternative 8-3: Modification/Replacement of Schoonmaker Road	In future
Alternative 8-4: Modification/Replacement of Zimmer Road Bridge	Y
Alternative 8-5: Modification/Replacement of Sholtes Road Bridge	Y

Alternative	Recommended for Implementation?
Alternative 8-6: Modification/Replacement of the NYS Route 443 Bridge (Lower)	In future
Alternative 8-7: Development of Sediment Management Plan	Y
Alternative 8-8: Bank Erosion Repairs	Y
Focus Area #9 – Gallupville	
Alternative 9-1: Modification/Replacement of School Street Bridge	N
Alternative 9-2: Floodplain Enhancement	N
Alternative 9-3: Individual Building Relocation, Elevation, Floodproofing	Y
Focus Area #10 – Railroad Bridge over Schoharie Creek	
Alternative 10-1: Modification/Replacement of Canadian Pacific Railroad Bridge	N
Alternative 10-2: Compliance with and Enforcement of NFIP Criteria	Y
Focus Area #11 – Cobleskill Creek Confluence	
Alternative 11-1: Modify/Replace Church Street Bridge	N
Alternative 11-2: Modify/Replace Route 30A Bridge and Roadway	N
Alternative 11-3: Individual Building Relocation, Elevation, Floodproofing	Y
Alternative 11-4: Roadway Signage and Closure	Y
Focus Area #12 – Fly Creek	
Alternative 12-1: SCSWCD Natural Channel Design Scenario #1	N
Alternative 12-2: SCSWCD Natural Channel Design Scenario #2	Y
Alternative 12-3: Develop a Sediment Management Plan	Y
Focus Area #13 – Colyer Road, Burtonsville	
Alternative 13-1: Modification or Enhancement of Channel or Floodplain	N
Alternative 13-2: Individual Building Relocation, Elevation, Floodproofing	Y
Focus Area #14 - Warnerville Cutoff	
Alternative 14-1: Elevation of the Roadway	N
Alternative 14-2: Elevation of Roadway and Installation of Bypass Culvert	N
Alternative 14-3: Elevation of Roadway and Installation of Bypass Bridge	N
Alternative 14-4: Warnerville Cutoff Roadway Signage and Closure	Y
Focus Area #15 – Potential for Flood Attenuation in Upper Watershed	
Alternative 15-1: Potential for Flood Storage at Warner Lake	N
Alternative 15-2: Potential for Flood Storage at Onderdonk Lake	N
Alternative 15-3: Potential for Flood Storage at Other Lakes, Ponds, and Wetlands	conserve wetlands
Focus Area #16 – Review of Berms along Farm Fields	
Alternative 16-1: Removal of Agricultural Berms	where possible
Focus Area #17 – Review of Potential for Flood Attenuation in Reservoirs	
Focus Area #18 - Recommendations for Protection of Watersheds, Wetlands, Floodplains	
Use Green Infrastructure and Best Management Practices	Y
Establish and Maintain Vegetated Buffers	Y
Protect Forests and Open Space	Y
Protect and Reconnect Floodplains	Y
Develop Guidelines to Limit Impervious Surfaces	Y
Implement Watershedwide Wetland, Stream, and Buffer Protection	Y

1.0 INTRODUCTION

1.1 Project Background

The SCSWCD has retained MMI to complete a Flood Mitigation Study for the Lower Schoharie Creek watershed. Funding for this study has been provided from the NYSDOS under Title 11 of the Environmental Protection Fund for the Local Waterfront Revitalization Program. The study is part of Phase 1 of the Mohawk River Watershed Management Plan implementation.

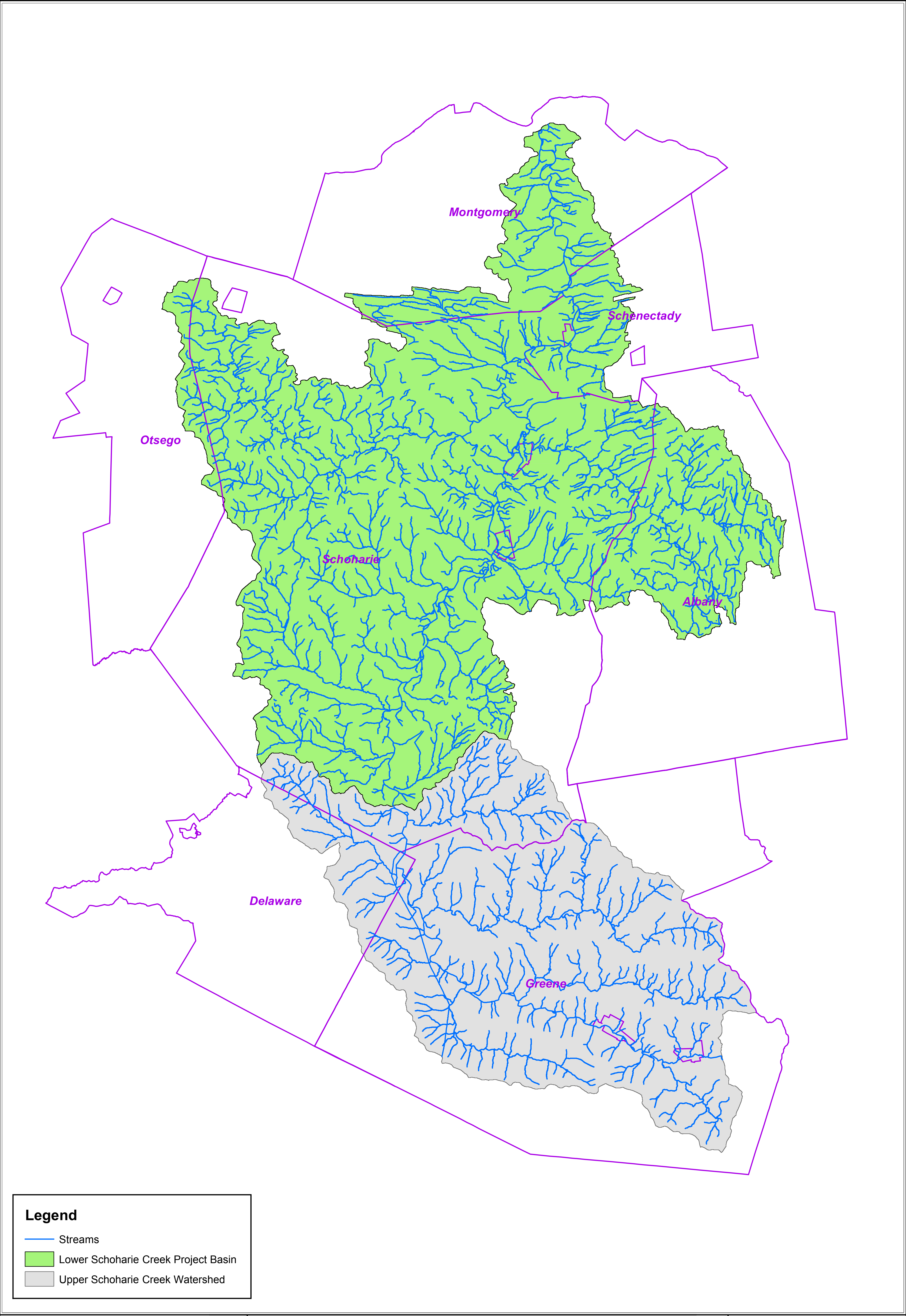
The subject Lower Schoharie Creek Flood Mitigation Study is an engineering feasibility analysis that develops a range of flood hazard mitigation alternatives, with the primary focus of identifying options that reduce flood elevations and inundation. During the completion of this study, MMI worked closely with the SCSWCD, elected officials, and members of the public who own homes or businesses within the watershed. Input from these individuals informed a greater understanding of flood damages and impacts and enabled a process of vetting flood mitigation alternatives.

1.2 Study Area

With a watershed of approximately 930 square miles, Schoharie Creek drains the northwestern Catskill Mountains. A tributary to the Mohawk River, Schoharie Creek flows through Schoharie County from south to north. The terrain within the watershed is a mix of mountainous landscapes and flat, narrow valleys. The elevation ranges from an average of about 1,200 feet in the northern limestone plateau section of the county to approximately 2,000 feet in the higher plateaus in the southern part of Schoharie County, with the headwaters in Greene County at an elevation of 4,000 feet (Schoharie County All-Hazards Mitigation Plan, 2006).

The Lower Schoharie Creek basin, comprising nearly two-thirds of the entire Schoharie Creek watershed, covers an area of 612 square miles and is 61 miles in length. The lower watershed extends into five counties, with the majority of the basin located within Schoharie County and small sections of the basin area located within Otsego County to the west, Montgomery County to the north, and Schenectady and Albany counties to the east. Figure 1-1 depicts the overall Schoharie Creek watershed and the Lower Schoharie Creek basin. Table 1-1 presents a list of the counties and towns that are located within the basin as well as the particular villages, hamlets, and place names that are referenced within this report.

The Schoharie Creek watershed includes numerous major tributaries as well as many smaller unnamed tributaries. The major tributaries are listed in Table 1-2. The course of Schoharie Creek includes two reservoir-dam systems: The Blenheim-Gilboa Dam, which is owned by the New York Power Authority (NYPA) and used to produce hydroelectric power, and the Schoharie Reservoir, a part of the New York City Water Supply System (FEMA, 2012 - Schoharie County Flood Insurance Study [FIS]).



SOURCE(S):

USGS StreamStats Version 3.0 (04/2016)
USGS National Hydrography Dataset (04/2016)
NYS GIS Clearinghouse (04/2016)

Figure 1-1: Schoharie Creek Watershed

Location:
Schoharie Creek Watershed, NY

Schoharie Creek Flood Study

Map By: EMH
MMI#: 4805-05
MXD: Q:\Projects\2884-08 Conesville LFA\GIS\Figure 1-1 Overall Schoharie Basin.mxd
1st Version: 04/25/2016
Revision: 8/25/2016
Scale: 1 in = 25,000 ft

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TABLE 1-1
Place Names within the Lower Schoharie Creek Watershed

County	Town	Village/Hamlet/Place Name
Otsego County	Cherry Valley	
	Decatur	
	Roseboom	
	Worcester	
Montgomery County	Charleston	Burtonsville
	Florida	
	Glen	
	Root	
Schenectady County	Duanseburg	
Albany County	Berne	West Berne
	Knox	
Schoharie County	Blenheim	North Blenheim
	Broome	Hauversville, Livingstonville
	Carlisle	
	Cobleskill	
	Esperance	Central Bridge, Sloansville
	Fulton	Breakabeen, Fultonham, West Fulton
	Gilboa	
	Jefferson	
	Middleburgh	Huntersland, East Cobleskill
	Richmondville	Warnerville
	Schoharie	Ecker Hollow
	Seward	
	Sharon	Sharon Springs
	Summit	Charlotteville, Clapper Hollow
	Wright	Galupville, Shutters Corners, Fox Creek, Echo Pond

TABLE 1-2
Major Tributaries within the Lower Schoharie Creek Watershed

Major Tributaries within the Lower Schoharie Creek Watershed		
Cobleskill Creek	Mill Creek	Fly Creek
Fox Creek	Line Creek	Little Schoharie Creek
Stony Creek	House Creek	West Kill
Mill Creek	Keyser Kill	Irish Creek
Wilsey Creek	Stony Brook	Ox Kill
Louse Kill	Switz Kill	House Kill
West Creek	Cole Brook	Betty Brook
Platter Kill	Beaverdam Creek	Panther Creek
Heathen Creek	Wharton Hollow Creek	Cripplebush Creek
King Creek		

The Lower Schoharie Creek basin was selected by the SCSWCD for analysis as a result of the highly floodprone nature of the region that has sustained extensive damage due to flooding, particularly in the recent past. While the entire Schoharie Creek basin is highly floodprone, the upper basin in Greene County has already been the subject of flood analyses funded by the NYCDEP through a number of Local Flood Hazard Mitigation Analyses (LFHMAs) and Local Flood Analyses (LFAs). As a result, there is a greater need to focus on the Lower Schoharie Creek basin. Much of the lower basin is located in Schoharie County, with a population in 2010 of 32,749 people. This area had long been inhabited by the Mohawk Indians, with the British establishing counties in the 1680s. Over time, the area has been sparsely settled, with the primary industry in Schoharie County being agriculture, predominantly dairy farming. More densely populated areas were settled in locations such as Middleburgh, Schoharie, and Cobleskill.

1.3 Nomenclature

All references in this document to right bank and left bank of Schoharie Creek and its tributaries refer to "river right" and "river left." The reference and orientation assumes that the reader is standing in the river looking downstream.

In order to have a common standard, FEMA's NFIP has adopted a baseline probability referred to as the base flood. The base flood has a 1 percent (one in 100) chance of occurring in any given year. In this report, the 1 percent annual chance flood is also referred to as the *100-year flood event*. Other reoccurrence 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* (0.5 percent annual chance flood).

2.0 WATERSHED INFORMATION

2.1 Initial Data Collection

Initial data collected for this study and analysis included publicly available information as well as input from soil and water county district representatives from each county, elected officials, and from the public. A brief discussion of major data sources follows.

FIS

FEMA FISs are available for all five counties within the Lower Schoharie Creek basin: Schoharie County (study dated February 16, 2012), Otsego County (study dated September 30, 2009), Schenectady County (study dated September 30, 2009), Montgomery County (preliminary study dated September 30, 2011), and Albany County (preliminary study dated March, 1, 2012).

For Schoharie County, FEMA's revised hydraulic analysis and floodplain mapping (effective in February 2012) were completed using aerial topographic maps produced from 2001 photographs. An important byproduct of an FIS is the Hydrologic Engineering Center – *River Analysis System* (HEC-RAS) computer model that is available for professional use and a key component of the subject study. The digital FIRM depicts the areas of predicted flooding during the 100-year frequency event, which frequently extend 500 feet to 1,000 feet or more on either side of Schoharie Creek. The area predicted to be flooded during the 100-year frequency event is known as the SFHA.

Stream Gauging Network

The United States Geological Survey (USGS) operates and maintains six active stream flow gauges within the Lower Schoharie Creek watershed. These gauges record daily stream flow, including flood flows. This data is essential to understanding long-term trends and is covered in more detail in the hydrology discussion in this report. Gauge data can be utilized to determine flood magnitudes and frequencies. Additionally, real time data is available at certain gauges to monitor water levels and provide flood alerts. Stream flow data and water levels are available at http://nwis.waterdata.usgs.gov/nwis/peak.

In addition to the USGS gauges, SCSWCD has established stream gauges in the watershed that measure water surface elevation and provide early warning alerts when certain water levels are reached or when water surface elevations undergo a rapid rise. These gauges are located on Schoharie Creek at Middleburgh and Esperance and on Fox Creek in Schoharie. Additional information on the stream gauging network is included in the hydrology section of this report.

Schoharie County Multi-Jurisdiction All-Hazard Mitigation Plan

The 2013 Schoharie County Multi-Jurisdictional All-Hazard Mitigation Plan provides a concise summary of the flood characteristics of the Schoharie Creek watershed with the purpose of giving Schoharie County and its municipalities a plan for implementing hazard mitigation projects that will minimize disaster impacts and losses.

According to the 2013 Schoharie County All-Hazard Mitigation Plan, 29 flood events have occurred since 1996, 13 of which have had major or significant community impacts. The average recurrence is one to two flood events each year in Schoharie County with a 72 percent chance each year of having a flood with significant community impacts. There is a 56 percent chance each year of a flood that will result in federal disaster declaration. In 1996, six separate flood events occurred, and in 2003, four flood events occurred. The villages and hamlets along the course of Schoharie Creek, including Gilboa, Blenheim, Fulton, Middleburgh, Schoharie, and Esperance, are most vulnerable to flood impacts and losses.

The After-Action Report and Improvement Plan prepared after the flooding in 2011 identified Fox Creek-Warner's Lake, West Kill, Cobleskill Creek, Fly Creek, Little Schoharie Creek, and Line Creek as areas where tributary flooding occurred and should be targeted for future monitoring.

The 2006 and the 2013 Schoharie County All-Hazards Mitigation Plans suggest the following recommendations for Schoharie County:

- Where not already completed, local municipalities should consider implementing land use regulations to limit the ability of private property owners to rebuild in high-hazard floodplain areas.

- All municipalities in Schoharie County should participate in the NFIP. Construction standards for structures in the mapped 100-year floodplain or floodway have been regulated through flood damage prevention laws since the 1980s. Each municipality has a designated floodplain administrator for whom proper orientation and training should continue to be a priority.

- Implement stormwater management projects such as improving roadway infrastructure (i.e., culverts and drainageways), extending sanitary sewers, or enacting local laws that limit the percent of impervious cover within a parcel or that require implementation of erosion control techniques during construction.

- Continued encouragement of stream stabilization projects throughout the watershed

- Continued participation and encouragement for funded buyouts of repetitive loss properties (RLPs) as well as land located within the floodplain (for example, approximately 100 floodplain acres have been acquired in the county and the land protected as open space).

- All Schoharie County jurisdictions should participate in the NFIP. The NFIP identifies properties that have been repeatedly flooded and where multiple claims for flood losses have been made through the NFIP fund. There are 265 properties located in high-risk flood zones (Zone A) that carry NFIP coverage. Approximately 38 percent of all NFIP claim costs were the result of damage to RLPs. There are 67 RLPs and one Severe Repetitive Loss Property (SRLP) identified in Schoharie County. The NFIP targets RLPs and sets priorities to use hazard mitigation grant funds to buy out or retrofit RLPs. The NFIP also plans to phase out coverage or begin charging full and actuarially based rates for RLP owners who refuse to accept FEMA's offer to purchase or mitigate the effect of floods on their structures.

  The one property in Schoharie County that was identified as a SRLP was located in the town of Middleburgh and received more than $89,000 in payments over the course of four flood events. More than 1,880 property owners, families, and residents from Schoharie County applied for disaster relief due to the flooding in August and September 2011 from Tropical Storms Irene and Lee. This was the greatest number of applicants for any New York county affected by these back-to-back flood events.

Fifty-five properties located in the high-risk A zones that were damaged by the 2011 floods have been approved for buyouts and demolition. Building officials determined that 657 homes in the 15 towns and villages affected by the floods sustained major damage, and repair costs for residential structures are expected to reach $90 million. One hundred floodplain acres have been acquired, and five homes, most having historic significance, have been elevated.

In 2004, Schoharie County received a State Archives and Records Administration grant for equipment, training, and software to better organize the county Geographic Information System (GIS) database. Several of the methods used to estimate potential losses for certain hazards will be modified and improved as the data contained within the Schoharie County GIS is further developed.

In terms of promoting flood awareness, training, and education, Schoharie County produced a 30-minute flood education video to run annually on local cable stations and to distribute to schools and libraries within the county. Additionally, using New York State Department of Environmental Conservation (NYSDEC) funds, the county installed 61 signs at locations where roads intersect SFHAs or at municipal boundaries. The signs state "Flood Zone Regulation in Effect" and have been useful in prompting questions from the general public about flood issues.

Water Quality Reports

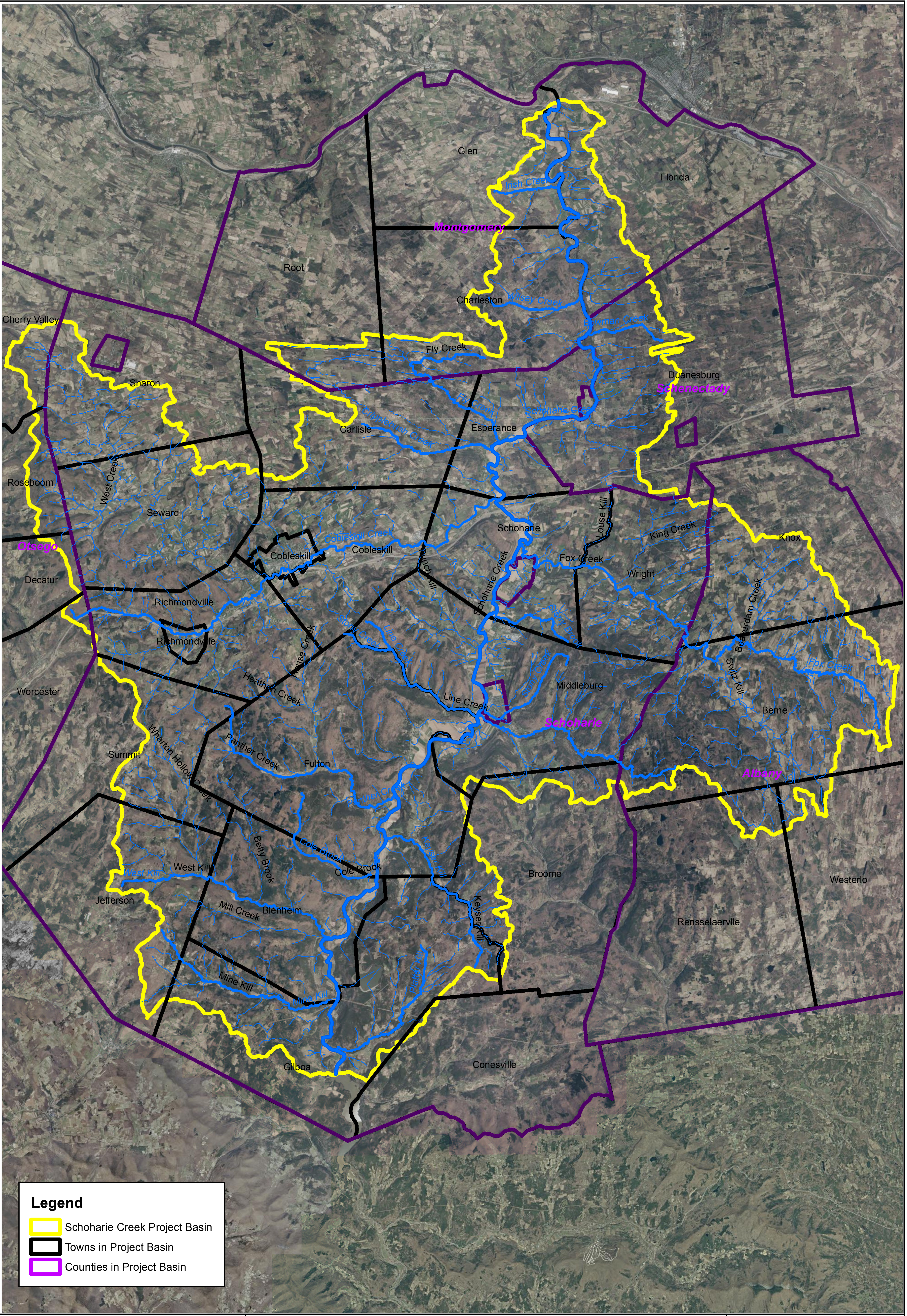
For the entire watershed, NYS's 2014 Section 303(d) inventory only lists Cobleskill Creek and its tributaries as impaired. As such, a Total Maximum Daily Load (TMDL) assessment is required for Cobleskill Creek due to pathogens from an on-site water treatment system (WTS). No other tributaries within the Lower Schoharie Creek watershed have been listed.

2.2 Field Assessment

Initial field investigations were conducted during late 2015 and early 2016. MMI staff conducted on-the-ground assessments and visual inspections throughout the Lower Schoharie Creek basin. The inspections included visual assessment of the riparian corridor, visible infrastructure within the corridor, and existing land use and development patterns. The streambed and banks, riparian cover, and channel structure were noted as were key drainage system outfalls that discharge into the creeks, dams, weirs, bridges, culverts, and other structures in and along the creeks. Photographic documentation was undertaken with select elements being incorporated into subsequent presentations/reports. The emphasis of these inspections was placed on the conveyance of floodwaters, sediment, and debris. Data gathered during field investigations were documented in GIS and Google Earth.

2.3 Watershed Land Use

Figure 2-1 is a watershed map of the Lower Schoharie Creek watershed. Schoharie Creek flows through or borders 10 towns including the towns of Gilboa, Blenheim, Fulton, Middleburgh, Schoharie, Esperance, Duanseburg, Charleston, Florida, and Glen. The Lower Schoharie Creek drains an area of 612 square miles and outlets into the Mohawk River at a point 61 miles downstream of the Gilboa Dam. The Schoharie Creek basin is 76 percent forested (*StreamStats*, 2015) with a mix of agricultural uses located primarily in the river valley, residential and commercial land uses concentrated in and around the hamlets, and rural residential uses outside of the hamlets.



SOURCE(S):

USGS StreamStats Version 3.0 (04/2016)
USGS National Hydrography Dataset (04/2016)
NYS GIS Clearinghouse (04/2016)

Figure 2-1: Lower Schoharie Creek Watershed Map

Location:
Schoharie Creek Watershed, NY

Schoharie Creek Flood Study

Map By: EMH
MMI#: 4805-05
MXD: Q:\Projects\4805-05 Schoharie Basin Flood Analysis\GIS\MXD\Figure2-1ProjectBasinMap.mxd
1st Version: 04/25/2016
Revision: 9/22/2016
Scale: 1 in = 17,500 ft

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Major population centers within the basin are the town and village of Cobleskill, population of 11,303; the town and village of Esperance, population 2,421; the town and village of Middleburgh, population 5,246; and the town and village of Schoharie, population 4,127 (U.S. Census Bureau, 2010). Other land uses include the SUNY Cobleskill College campus, several limestone quarries, and three natural gas and propane pipelines that traverse the county.

2.4 Watershed and Stream Characteristics

The Schoharie Creek watershed is asymmetrical in shape, with a south-to-north orientation. It has very steep, mountainous slopes that flow into a broad valley. The terrain within the watershed is a mix of mountainous landscapes and flat, narrow valleys while the main channel of Schoharie Creek flows through a broad, flat-bottomed valley. The elevation ranges from an average of about 1,200 feet in the northern limestone plateau section of the county to approximately 2,000 feet in the higher plateaus in the southern part of Schoharie County, with the headwaters in Greene County at an elevation of 4,000 feet (Schoharie County All-Hazards Mitigation Plan, 2006).

The length of the Schoharie Creek from its headwaters on Blackhead Mountain to its outlet at the Mohawk River is 98.5 miles. The portion of the Schoharie Creek that is the focus of this study extends from just downstream of the Gilboa Dam to the confluence with the Mohawk River and is 61 miles. Schoharie Creek can be characterized as an alluvial river, meaning its channel is located on sediment previously placed by the river. Alluvial rivers adjust their shape, size, and slope in response to flow rates and sediment loads. Schoharie Creek and its tributaries flow over exposed bedrock in several locations.

Along the general course of the river, surficial geology is recent alluvium, which consists of oxidized fine sand to gravel and may be overlain with silt in the valley floodplains. The watershed as a whole is predominantly underlain with till of variable texture and usually poorly sorted sand, a result of deposition from glacial ice, with permeability and thickness varying. The underlying bedrock within the watershed consists of shale, limestone, and greywacke (NY State Museum, 2015).

2.5 Hydrology

USGS operates and maintains stream flow gauges that record daily stream flow, including flood flows. This data is essential to understanding long-term trends. Gauge data can be utilized to determine flood magnitudes and frequencies. Table 2-1 is a list of active and inactive (historic) USGS water surface stream gauging stations within the lower watershed from north to south. This portion of the Schoharie Creek watershed extends to five counties: Schoharie County, Otsego County, Schenectady County, Albany County, and Montgomery County.

FEMA FISs are available for each county, including Schoharie County in the center, Otsego County to the west, Montgomery County to the north, and Schenectady and Albany counties to the east. The purpose of a FEMA FIS is to determine potential floodwater elevations and delineate floodplains to identify flood hazard areas and establish flood insurance rates.

The hydrologic analysis methods employed by FEMA throughout the study area follow the standardized regional regression equation procedure detailed by the USGS publication 90-4197, *Regionalization of Flood Discharges for Rural, Unregulated Streams in New York, Excluding Long Island*. This procedure relates runoff discharge to the mean annual precipitation and several other parameters based on watershed basin characteristics within a number of geographically distinct regions in NYS. The Schoharie Creek watershed falls within USGS Regions 4 and 4a for NYS. The parameters required for the Region 4 regression equations included mean annual precipitation, watershed area, and basin storage. Basin storage is defined by USGS as the percentage of the area within a watershed covered by lakes, ponds, or swamps (FEMA, 2008).

TABLE 2-1
USGS Gauging Stations within the Lower Schoharie Creek Watershed

USGS Gauge Number	Location	Drainage Area (sq. mi.)	Period of Record	Active?
01351500	Schoharie Creek at Burtonsville	885	1939-2015	Yes
01350900	Beaverdam Creek near Knox	7	1963-1974	No
01351000	Fox Creek at West Berne	67	1925-1974	No
01350500	Schoharie Creek at Middleburgh	534	1909-1976	No
01350355	Schoharie Creek at Breakabeen	444	1975-2015	Yes
01350200	West Kill at North Blenheim	45	1975-1987	No
01350180	Schoharie Creek at North Blenheim	358	1969-2015	Yes
01350140	Mine Kill near North Blenheim	16	1975-2015	Yes
01350120	Platter Kill at Gilboa	11	1975-2015	Yes
01350101	Schoharie Creek at Gilboa	316	1936-2015	Yes

sq. mi. = square mile

Table 2-2 lists peak discharges for the 10-, 50-, 100-, and 500-year flood events at various points along the Schoharie Creek within the study area as determined by FEMA and reported in the FIS for each county.

TABLE 2-2
Schoharie Creek FEMA Peak Discharges (all flow values in cfs)

Location	Nearest USGS Stream Gauge	Drainage Area (sq. mi.)	10-year flood event	50-year flood event	100-year flood event	500- year flood event
At downstream corporate limits of town of Esperance	Burtonsville	886.3	43,200	71,100	85,700	128,000
At the upstream corporate limits of town of Schoharie	Middleburgh	550.42	42,032	69,178	83,383	124,540
At the downstream corporate limits of village of Middleburgh	Middleburgh	546.43	42,018	69,155	83,356	124,499
At downstream corporate limits of town of Fulton	Breakabeen	504.09	41,872	68,915	83,066	124,066

sq. mi. = square mile cfs = cubic feet per second

In addition to the USGS gauges, SCSWCD has established stream gauges in the watershed that measure water surface elevations in 15-minute intervals. These gauges are located on Schoharie Creek at Middleburgh and

Esperance and on Fox Creek in Schoharie. Following Tropical Strom Irene in August 2011, the USGS sent personnel to survey the high water marks (HWMs) in 30 locations throughout the Schoharie basin (USGS, 2014).

Hydrologic data on peak flood flow rates within the Lower Schoharie Creek basin are also available from the USGS *StreamStats* program. *StreamStats* is a web-based GIS that is used to access stream flow statistics, drainage basin characteristics, and other information for selected sites on streams. Basin characteristics include drainage area, stream slope, mean annual precipitation, and percentage of forested area.

For the purpose of the subject study, peak flow rates determined by FEMA are used where available. For analysis within portions of the watershed where no FEMA flows have been determined, *StreamStats* was used to estimate peak flow rates.

3.0 EXISTING FLOODING HAZARDS

3.1 Flooding History in the Schoharie Creek Basin

The Schoharie Creek basin is particularly prone to flooding due to a number of factors, including the location of its headwaters in the Catskill Mountains; the low permeability of the mountainous landscape; the lack of wetland habitats or lakes within the watershed to retain stormwaters; and the prevalent winds, which during coastal storms push the storm air masses up and over the mountains, causing cooling and subsequently high amounts of precipitation. As the wettest region in NYS with over 60 inches of precipitation annually, rainfall events of 5 inches are common. These and other factors contribute to the flash flood conditions within the basin.

A number of documents have been reviewed to assess the flood history within the Schoharie Creek Watershed basin. According to the *History of Schoharie County Floods* (2012), which reviewed historic newspaper articles and personal recollections, 41 major floods have occurred within the Schoharie Creek basin from 1784 to 2011 (Schoharie County Historical Society, 2012). Since that publication, an additional flood occurred in summer 2013. The USGS published a report entitled *Floods of 2001 in New York*, which focuses, in part, on the impact of Tropical Storm Irene within the Schoharie Creek basin (Lumia et al., 2014). Table 3-1 provides a summary of the 42 floods that have occurred since 1784. Beginning in March 1940, a USGS stream gauging station on the Schoharie Creek at Burtonsville (gauge #01351500) was installed to record discharge levels (peak stream flow) and other parameters. Where available, discharge levels are noted in Table 3-1. A time line is presented in Figure 3-1.

TABLE 3-1
Summary of Major Floods within the Schoharie Creek Watershed

Storm #	Date	Comments	Discharge at USGS Gauge Schoharie Creek at Burtonsville NY (cfs)
1	spring 1784	Flooding triggered by ice jams, extensive damage, people petitioned to be exempt from taxation. Waters overtopped banks and damaged farmland and destroyed many buildings.	unknown
2	Jan 31, 1839	Flood on Schoharie Creek and tributaries. Water suddenly rose 26 feet. Records of damage in Esperance include destruction of tannery, sawmill, bridges, gristmill, homes, stores, lumber, and tools.	unknown
3	Nov 15, 1849	Schoharie Creek flooded 4 feet higher than in the past 20 years. Farm animals were lost. In Middleburgh, milldams, bridges, corn crops and fences were damaged. A Mill store (now today's Mill Farm Greenhouses) was destroyed.	unknown
4	May 3-4, 1854	Creek overflowed. Timber and saw logs carried away by creek. Plank Roads in Schoharie, Richmondville, and Middleburgh were damaged. Loss of bridge at North Blenheim.	unknown

Storm #	Date	Comments	Discharge at USGS Gauge Schoharie Creek at Burtonsville NY (cfs)
5	Aug 2, 1856	Very high flows. Fields submerged, bridges washed away, and barns, fences etc. were destroyed. A low estimate of $50,000 in damages was given for the southern parts of Schoharie County. In Blenheim, a bridge was badly damaged.	unknown
6	Feb 12, 1857	Toll bridge across the Schoharie was badly damaged. Bridge at Middleburgh, originally built in 1813, was completely destroyed. Central bridge over the Schoharie and the Richmond Plank Road were badly damaged.	unknown
7	spring 1869	Seventy bridges in the town of Berne were reported destroyed.	unknown
8	Oct 7, 1869	Schoharie Creek flooded 22 inches higher than ever before. In the southern part of the county, nearly all bridges were carried away. The Schoharie railroad line, numerous roads, a kiln, gristmill, barns, and crops were all badly damaged.	unknown
9	1871	Flooding was reported on the Westkill Creek in North Blenheim. Flooding damaged a total of eight bridges and 70 miles of roads in Schoharie County, and the course of the Schoharie Creek was altered.	unknown
10	June 7, 1874	Flooding reported in many locations. Channel was four times its usual width, and much of the best farmland was washed away. Roads and bridges were badly damaged, and crops were badly or entirely destroyed.	unknown
11	Sep 1, 1885	Very high flows from tributaries caused damage to livestock and many bridges. Stores, barns, and a machine shop were damaged. Damage to crops (especially hops) was estimated at $10,000. The railroad line was damaged. In Sharon Springs, many buildings were washed away or destroyed.	unknown
12	Sep 24, 1885	Eight bridges washed away in the town of Summit in Schoharie County.	unknown
13	Dec 15, 1901	Schoharie River reached highest levels in 32 years, and according to historic reports, this flood was 2nd only to the 1869 flood. In Schoharie Village, the flats were flooded, the railroad tracks were covered, and cellars were filled. Bridges and roads were damaged or destroyed throughout the basin. Houses and buildings were flooded.	unknown
14	March 6, 1902	The Schoharie Creek expanded over the flats; ice jams caused damage to one of the piers of Middleburgh Covered Bridge. Bridges were carried away at Shutters Corners and at West Berne on the Fox Creek.	unknown
15	July 24, 1902	There was great damage to crops, highways, and railroads due to heavy rains.	unknown
16	Oct 15, 1903	Flood greater than the 1869 flood resulting from over 10 inches of rain within 24 hours. The flooding destroyed crops, fences, buildings, roads, bridges, dams, and hop poles. Homes and businesses had cellars flooded.	unknown
17	March 21, 1912	Charlotteville reported a large flood with the whole village flooded and many cellars filled with water.	unknown
18	August 1915	There was extensive damage from this flood. In Middleburgh, Huntersland Stream and Little Schoharie flooded homes and property, damaged roads, and destroyed livestock and farm equipment. Every bridge with the exception of the one at Krumm's Falls, on the Keyserkill was swept away, and many roads were swept away. In Broome, 48 bridges were washed away or undermined.	unknown

Storm #	Date	Comments	Discharge at USGS Gauge Schoharie Creek at Burtonsville NY (cfs)
19	Feb 14, 1923	The Town of Jefferson reported a large flood where two bridges washed away, and another bridge, one made of iron, was moved; roads were washed out, and deep gullies were made. Taxes had to be raised "abominably" as a result.	unknown
20	July 12, 1928	In Schoharie, floodwaters rose 10 feet above the low water mark and washed away a temporary bridge at Bridge Street.	unknown
21	March 18-19, 1936	Schoharie County reported the worst flood since 1903. Melting snow and continuous rain caused Schoharie and tributaries to overrun their banks. In the village of Schoharie and town of Middleburgh, great flooding was reported. Main Street in Middleburgh flooded as well as the high school and other roads. Thousands of dollars of damage. Bridges on smaller streams washed out. The Civilian Conservation Corp workers rescued families from flooded homes in Livingstonville.	unknown
22	Sep 22, 1938	This storm was also known as the New England Hurricane or The Long Island Express. Flooding occurred throughout the basin from the Cobleskill Fairground to Schoharie village. Many bridges were destroyed. Telephone service was disrupted due to falling trees severing telephone lines. Rivers changed their courses.	unknown
23	March 31, 1940	In the village of Middleburgh, Main Street flooded with 18 inches of water and ice.	25,200
24	March 30, 1951	In Middleburgh, four men were trapped in four separate automobiles in floodwaters on Route 145 and Route 30. All were rescued.	37,900
25	Aug 19, 1955	Flooding resulting from two hurricanes (Connie and Diane, still the wettest tropical cyclones to hit the Northeast U.S.) in less than a week. Crops and farmland flooded. Schoharie Creek rose 5 feet above normal depth.	13,300
26	Oct 17, 1955	A 100-year flood on the Schoharie and Catskill Creeks caused by 16 to 18 inches of rain over the Tannersville area. Worst flood in county history up to this point. Primarily hit Schoharie and Middleburgh. Water spilled over Gilboa Dam, and the Schoharie Creek grew to a half mile to a mile wide. There was extensive damage to homes, businesses, and farmland including crops and livestock. Electricity was out for 3 days, and telephones were out for 2 weeks. Roads were flooded and badly damaged.	76,500
27	Sep 12, 1960	Flooding due to Hurricane Donna. In the morning, water was 33' below crest of Gilboa Dam. In 18 hours, the reservoir was full and spilling over the dam. Flooding was terrible upstream of the dam and outside of the focus area for this report.	30,500
28	March 11, 1964	Ice jams on Cobleskill Creek and its tributaries lead to flooding. Cobleskill Fire Department had to rescue college students in a row boat.	29,400
29	June 23, 1972	Hurricane Agnes. Water was 2.5 feet over the spillway. This was caused by removal of clog near Harriman Dam in Tannersville (Greene County). Approximately 60 families were evacuated along Route 30 north of Blenheim. Family rescued from home in Blenheim. County estimated, in request to Department of Agriculture aid request, damages totaling $65,000.	28,500

Storm #	Date	Comments	Discharge at USGS Gauge Schoharie Creek at Burtonsville NY (cfs)
30	July 3-4, 1974	Heavy rain caused flooding throughout the basin. Roads in Middleburgh, Cobleskill, and Warnerville flooded. Bridge Street in Schoharie also flooded. There was extensive damage in West Middleburgh and Sharon Springs.	12,900
31	Dec 12, 1974	Three families, totaling eight people, were evacuated from homes along Schoharie Creek between Breakabeen and North Blenheim.	25,200
32	Oct 17, 1977	Four inches of rain fell within 24 hours. Homes evacuated, power outages, and roads coated with "slush."	22,800
33	March 22, 1980	Almost 10 inches of rain fell. Bridges washed out, roads closed, and communities isolated, including Middleburgh.	40,300
34	May 30, 1984	Schoharie, Catskill, and Fox Creeks flooded. Flooding closed roads in northern part of Cobleskill. Gravel supporting Delaware and Hudson Railroad tracks was washed away.	39,400
35	April 3-6, 1987	Coastal storm of 9 inches of rain. Extensive flooding and damage. Ten lives lost when NYS Thruway Bridge over Schoharie Creek collapsed. Middleburgh's Main Street flooded. Schoharie County estimates millions in damage.	64,900
36	Jan 19, 1996	Over 4.5 inches of rain fell, and as much as 45 inches of snow melted resulting in major flooding. Ice jams occurred. Two lives were lost in the village of Schoharie. Several houses were damaged or destroyed. Farmland was damaged and livestock drowned. Roads closed and some badly damaged. Damaged houses were purchased by FEMA and demolished.	81,600
37	Sep 18, 1999	Hurricane Floyd dropped up to a foot of rain in the Catskills.	26,100
38	April 2-3, 2005	There was an excessive rain event, and after a wet March with areas of frozen ground remaining, this led to flooding on all major rivers as well as small streams. Most significant flooding was on Schoharie Creek. Parts of Middleburgh and Schoharie were inundated. Roads were damaged with three to four dozen road closures. Homes were also damaged, and more than 40 families had to evacuate their residences. State of Emergency declared. Shelters set up and populated.	56,100
39	June 28, 2006	Torrential rain. Areas along Schoharie and Cobleskill Creeks experienced the most flooding, affecting the villages of Richmondville and Cobleskill. President Bush signed a major disaster declaration for NYS for cleanup efforts.	18,000
40	Oct 1, 2010	Six to nine inches of rain fell in Prattsville. Discharge was 3rd highest daily average recorded since records kept. Schoharie Reservoir did not overflow, which is attributed to a drought prior to storm.	12,300

Storm #	Date	Comments	Discharge at USGS Gauge Schoharie Creek at Burtonsville NY (cfs)
41	Aug 28, 2011	Hurricane Irene – Up to 14 inches of rain fell causing the Schoharie Creek to flood the entire valley from Gilboa to Esperance, including the villages of Blenheim, Breakabeen, Middleburgh, Schoharie, Gallupville, Old Central Bridge, parts of Sloansville, and Esperance. Largest flood that has been recorded. DEP lost power and was unable to monitor the Gilboa Dam. Sirens at the dam were triggered due to large quantities of rain. All those within the dam's projected flood zones (approximately 7 percent of Schoharie County) were evacuated. The Gilboa Dam held, and no lives were lost. 911 was down due to flooding. State of Emergency declared. Extensive flooding, road closures, and bridges out. The historic Old Blenheim Bridge was swept away. Then Tropical Storm Lee brought additional rain to the region on September 7, 2011.	128,000
42	June 13, 2013	Thunderstorms across Schoharie County produced flash flooding. Three inches of heavy rain in a short time overwhelmed drainage systems, damaged culverts and roads, and a State of Emergency was declared for the villages of Middleburgh and Schoharie and town of Schoharie. Shut down roads, soaked farm fields, flooded some homes and businesses, stranded motorists, and forced dozens of Middleburgh elementary students to remain in school for hours.	22,200

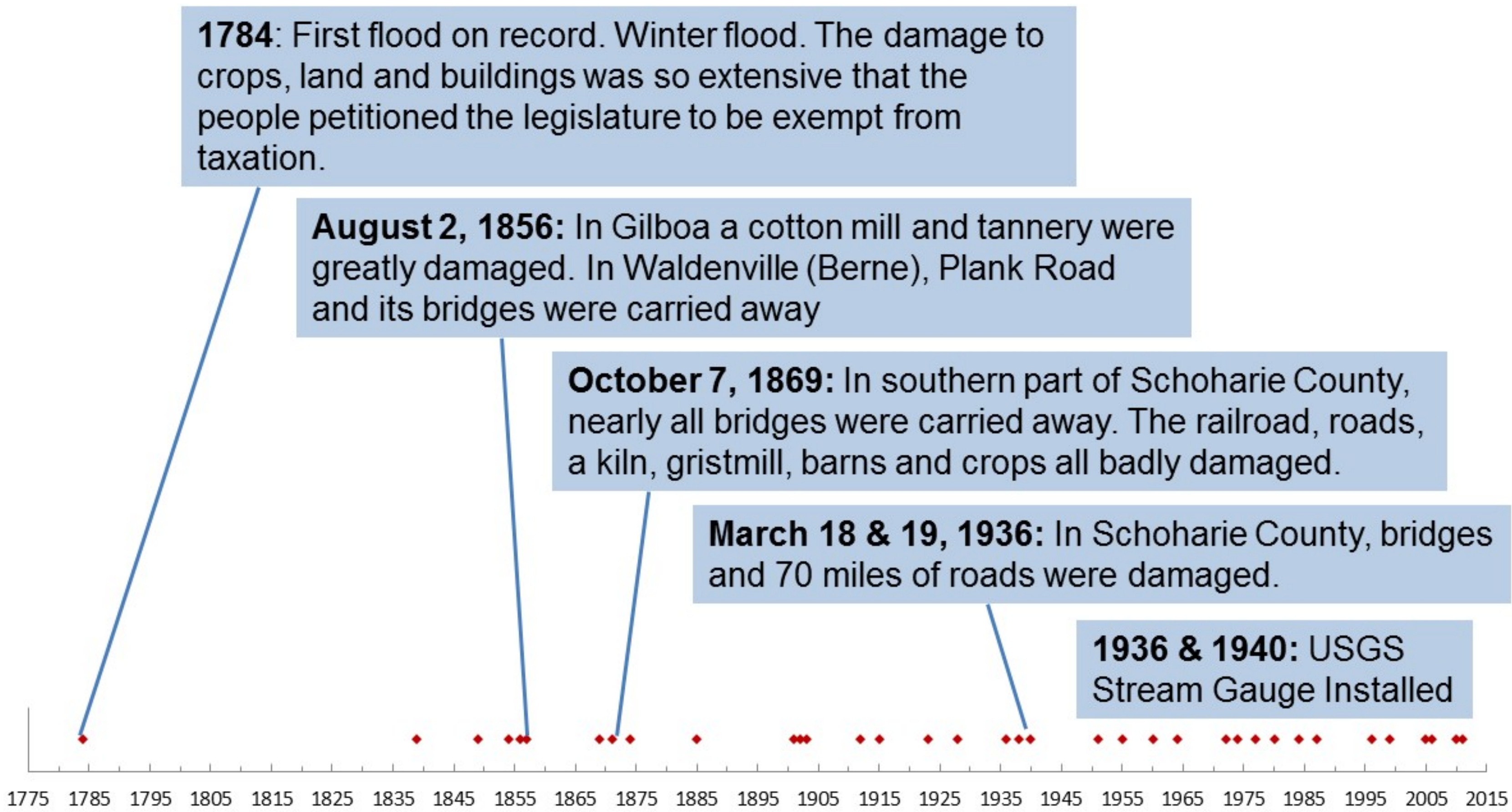
Of the 11 largest events on record, all but three were influenced by snowmelt. Other floods were due to hurricanes in October 1955 and two November rainstorms (FEMA, 2012 – Schoharie County FIS). Below is an expanded discussion of the larger or more significant floods within the basin. For flood events prior to 1940, peak discharge data is not available such that the precise magnitude of the flood is not known; however, personal stories and newspaper articles give a sense of the extent of the flooding damage.

The first flood on record occurred in the **spring 1784**, a year following the end of the American Revolution. The flooding was triggered by ice jams, causing damage to crops, land, and buildings that was so extensive the people petitioned the legislature to be exempt from taxation.

The flood on **August 2, 1856**, was described as, "*the most disastrous freshet ever witnessed in this county*" (Schoharie County Historical Society, 2012). On Fox Creek at Shutters Corners between Schoharie and Gallupville, a farmhouse containing two individuals was swept downstream. Also swept away were a barn, livestock, and grain. In Gilboa, a cotton mill and tannery were greatly damaged. In Waldenville, Plank Road was entirely washed away, and its bridges were destroyed. In Middleburgh, Judge Danforth's bridge was badly damaged. As noted in Table 3-1, damages for the southern portion of Schoharie County were given a low estimate of $50,000.

On **October 7, 1869**, with the Schoharie Creek a reported 22 inches higher than ever before, the Schoharie railroad line was damaged, a brick kiln was destroyed, and a barn near the creek was swept away. In Middleburgh, a gristmill and dam were damaged. In the southern part of the county, nearly all bridges were carried away.

Figure 3-1
Time line created from flood information in *History of Schoharie County Floods,* 2012. Schoharie County Historical Society



On **June 7, 1874**, flooding was reported in many locations within the basin, including in the upper section of Blenheim Village. The Westkill floodwater levels were very high and carried off a mill dam and bridge, a shoe shop, a house and barn, and another house (and 86 beehives). A tributary of the Westkill carried away a saw mill. Also washed away were bridges, mill dams, and roads in many places.

On **December 15, 1901**, the Schoharie River reached its highest levels in 32 years, and according to historic reports, this flood was second only to the 1869 flood. In Schoharie Village, the flats were flooded, the railroad tracks were covered, and cellars were filled. Bridges and roads were damaged or destroyed throughout the basin.

On **October 15, 1903**, according to historic accounts, a flood greater than the 1869 flood resulted from over 10 inches of rain within 24 hours. The flooding destroyed crops, fences, buildings, roads, bridges, dams, and hop poles throughout the basin. Homes and businesses had cellars flooded on Main Street, Foundry Street, and River Street in Middleburgh. The short bridge on the M&S railroad was moved from its foundation, and several washouts of the Schoharie Valley railroad were reported.

From a flood in **August 1915**, there was extensive damage throughout the watershed. In Middleburgh, Huntersland Stream and Little Schoharie flooded homes and property, damaged roads, and destroyed livestock and farm equipment. Similar damage occurred in Middleburgh and Broome, including 48 bridges that were washed away or undermined in Broome, and all bridges and portions of the road bed were washed away along Brooky Hollow Creek in the Huntersland portion of Middleburgh. Every bridge, with the exception of the one at Krumm's Falls, on the Keyserkill was swept away, and many roads were swept away.

On **March 18 and 19, 1936**, Schoharie County reported the worst flood since 1903. Melting snow and continuous rain caused the Schoharie Creek and tributaries to overrun their banks. Flooding damaged a total of eight bridges and 70 miles of roads in Schoharie County. In the village of Schoharie and town of Middleburgh, substantial flooding was reported. In addition, roads in Middleburgh, Breakabeen, Blenheim, Livingstonville, and Cobleskill were closed. Four bridges washed out: two in Livingston, one at Clauverwie Street in Middleburgh, and one in Gallupville. The Catskill Creek bridge was saved using ballast against the piers. Two homes were destroyed in the village of Blenheim. Crops were damaged and livestock killed. The Civilian Conservation Corp workers rescued families from flooded homes in Livingstonville where roads were flooded, and two bridges were washed away. Thousands of dollars of damage were estimated, and the course of the Schoharie Creek was altered.

On **September 22, 1938**, a storm, also known as the New England Hurricane or The Long Island Express, hit the region. The Cobleskill Fairground was covered in a few inches to 6 feet of water during the fair. Livestock was lost, some barns and trailers were washed away, and the grandstand, paddock, and racetrack flooded. Roads were closed including from Ecker Hollow to Middleburgh, and many bridges were destroyed. It was not possible to travel from West Fulton to Cobleskill due to the need for temporary bridges. Telephone service was disrupted due to falling trees severing telephone lines.

As a result of Hurricanes Connie and Diane, a 100-year flood event occurred on **October 17, 1955**, within the Schoharie Creek watershed. It was recorded that 16 to 18 inches of rain fell to the south over the nearby Tannersville area, considered the worst flood in Schoharie County history up to that point with Middleburgh and Schoharie sustaining the worst damage. A peak flow of 76,500 cfs was recorded at Burtonsville. Extensive damage occurred to homes, businesses, and farmland including crops and livestock. Electricity was out for 3 days, and telephones were out for 2 weeks. Roads were flooded and badly damaged.

Over 50 homes in Middleburgh were evacuated, and over 250 people took up shelter in the Schoharie school gymnasium as a result of the October 1955 flood. West Point amphibious duck boats were used to reach towns that were isolated and disconnected by flooding. A State of Emergency was declared in Middleburgh, Schoharie, and Cobleskill. The Red Cross surveyed Schoharie and found that 120 homes were evacuated, 40 had major damage (i.e., water above the first floor), and 6 had major structural damage. Typhoid clinics were set up, and milk pasteurizing plants were tested for contamination. Extensive damage to crops and property were reported, cows drowned, and farm equipment was destroyed. Governor Harriman and President Eisenhower petitioned to have appropriate agencies examine flooding in the Schoharie Valley.

From **April 3 to 6, 1987**, a coastal storm dropped over 9 inches of rain within the basin resulting in a peak discharge of 64,900 cfs. This storm is well remembered as 10 lives were tragically lost when the NYS Thruway bridge over Schoharie Creek collapsed. Extensive flooding and damage resulted throughout the county. Schoharie County estimated millions of dollars in damage.

On **January 19, 1996**, over 4.5 inches of rain and as much as 45 inches of snow pack melted, resulting in a peak flow of 81,600 cfs in Schoharie Creek. Ice jams occurred, exacerbating flooding. Extensive damage occurred to homes, businesses, farms, and roads, including 200 yards of Stryker Road. A large number of cows died due to hypothermia. Middleburgh had over $2.5 million in damage to residential property with 39 homes destroyed, 116 with major damage and 217 with minor damage. Due to recurrent damage from flooding, the cleanup effort for this flood involved purchasing and demolishing 15 homes on Stryker Road as well as moving a church and the Old Town Hall to higher ground.

Between **June 26 and June 28, 2006**, flooding was most severe in areas west of the Schoharie Creek; including the towns of Seward, Richmondville, Cobleskill, Summit, and Gilboa. Through Gilboa and around Cobleskill, 4 to 5 inches of rain fell in a short time, and as much as 6 inches fell in areas of Seward, Richmondville, and Summit. A great deal of damage was sustained, with up to $160,000 in damages reported to municipal roads, bridges, and other infrastructure. Two homes had major flood damage, and 60 others had minor damage. Seventy-three individuals and families applied for FEMA disaster aid. Approximately 35,125 acres, or 43 percent of the farmland in Schoharie County, were damaged, and extensive structural damage was also reported to farm properties.

By far the largest storm on record occurred on **August 28, 2011**, as Tropical Storm Irene dumped up to 14 inches of rain within the Schoharie basin, resulting in a peak flow of 128,000 cfs. This catastrophic flooding was followed by additional precipitation on **September 7, 2011**, as Tropical Storm Lee dropped a reported 2 to 7 inches of additional rain. The emergency 911 system was down due to flooding, and a State of Emergency was declared. For the first time in the Gilboa Dam's history, sirens were triggered. Eight thousand Schoharie County residents were inundated, with extensive damage to homes. According to a USGS report (2014) on the floods of 2011, "*Communities along Schoharie Creek were particularly hard hit. Local officials estimated that about one-third of homes and businesses in the village of Schoharie were destroyed as a result of the flooding. Similar destruction occurred within other villages (Prattsville, Middleburg, Esperance, and many others) along the creek*" (Lumia et al., 2014).

In NYS, over $1 billion in damages occurred, with 600 homes destroyed, six towns inundated, 150 major highways damaged, and 22 state bridges closed. Approximately 140,000 acres of farmland in NYS were destroyed, with damages upwards of $45 million.

In Schoharie County, well over $100 million in damages was estimated to have occurred. Schoharie County was part of President Obama's Disaster Declaration. The Schoharie County Emergency Management Main Street headquarters was evacuated due to flooding. Additional county offices on Main Street were badly damaged, including the Health Department, Department of Public Works, and the county jail. Inmates had to be transferred due to flooding. The estimate for damages to county property alone is in the double-digit millions. In Schoharie County, 908 structures were damaged, and 230 sustained damage equal to 50 percent or more of their value. Approximately 10,000 customers in Schoharie County were without power on September 1, 2011.

According to a December 16, 2015, article in the Watershed Post, the Schoharie County Corrections Office facility had been housed in, "*a dilapidated FEMA trailer with a portable outhouse for a bathroom,*" following Hurricane Irene. The trailer is described as a temporary solution that has far outlived its intended lifespan, with blackened air filters, a leaking roof, and an electrical panel that is hanging by its hinges, among other issues.

In Middleburgh, water rose 6 feet above the 100-year flood level. According to one resident's account, the floods of 1955 and 1996 pale in comparison to 2011 (Major Lamont). The Middleburgh Middle/High School sustained at least $5 million in damage, and it took more than 4 months for the Middleburgh Library to reopen, with 3,000+ books lost.

The Schoharie Town Hall sustained damage, and the firehouse lost most of its gear and equipment. Transformers exploded during flooding, and two large oil storage tanks from a fuel company business overturned, releasing pools of oil. In the village of Schoharie, 275 homes and businesses were significantly damaged. Most people did not have flood insurance. Of the 437 homes in the village of Schoharie, only 91 had policies. As of January 10, 2012, Mayor Borst of the Village of Schoharie estimated that of the 940 people in the village only 20 families have been able to return to their homes. The mayor estimated damages of $27 million. FEMA funded the rebuilding of Schoharie Fire Station with $900,000 in aid.

Towns throughout the basin sustained damage. The Blenheim historic covered bridge, built in 1855, was swept away. In the town of Broome, two houses were demolished, and nine were over 50 percent damaged. The damage to roads totaled $1.2 million within Broome. Due to a log jam and general flooding during Tropical Storm Irene, there was no way to evacuate the hamlet of Gallupville. A 1944 World War II vehicle was used to transport volunteers to haul debris. Several homes on Old Route 30 in Esperance were washed off their foundations, and a mobile home on Route 20 in Esperance was swept downstream by floodwaters.

The cleanup efforts following Tropical Storm Irene were described as immense. People used their own equipment to clear roads and to work within the creeks. Road crews dumped fill into creeks "*for protection*." Emergency operations were set up at the Cobleskill Fairgrounds, and rescues were made by air, boat, and ground. Local, state, and federal personnel responded. FEMA's Urban Search and Rescue teams from Ohio and Pennsylvania reported to the scene. The New York National Guard sent 2,500 soldiers to the region to aid in the cleanup efforts. The Salvation Army, Red Cross, and Niagara Mohawk also responded to aid in the cleanup effort. Fire departments from all over the northeast came to help pump out cellars. Numerous church groups from many different denominations helped people clean their homes as did a number of nonprofit groups. Power companies from as far away as Illinois also sent help.

The Red Cross set up "pods" with food, water, and supplies for people. Numerous recovery centers were set up for an extended period after the flooding to assist people with rebuilding their homes. Food cafes were set up in tents to serve meals to local residents. The food was donated from a number of sources, and volunteers served the food. A mobile laundromat was set up as were power relief stations with computers, satellite phones, Wi-Fi, and recharging stations.

As part of the cleanup efforts, monetary assistance came from numerous sources. The Schoharie County Storm Relief Assistance from NYS totaled $48.2 million. FEMA mobile homes were provided to anyone with more than $10,000 in damage. FEMA had difficulty finding locations outside of the 100-year flood zones to place the mobile homes. FEMA determined that the county jail would remain at its current location and be rebuilt within the floodplain. FEMA also determined that the Emergency Management Office would receive floodgates and other flood mitigation devices, and the E-911 centers would likely be moved. The National Grid provided a $6 million Emergency Economic Development Program following the storm. Five hundred eighty-four small businesses and nonprofits that sustained direct flood damage were awarded a total of $7.9 million in assistance from the Businesses Flood Recovery Grant Program. Hay was donated to farmers from upstate farmers.

According to New York Rising Community Reconstruction Plan (NYRCRP) publications for the towns and villages of Esperance, Schoharie, & Middleburgh (March 2014) and for the towns of Fulton and Blenheim (December 2014), the monetary damages within Schoharie County as a result of Tropical Storm Irene were staggering. Table 3-2 provides estimates of damages within different resource categories.

TABLE 3-2
Schoharie County Damage Estimates
Following Tropical Storm Irene (August 28, 2011)*

Resource	Damage Estimate
Crops and Other Agricultural Resources	$18.8M
Roads, Bridges, and Storm Sewers	$130M
Residences	$92.5M

*NYRCRP (March 2014 and December 2014)

The Gilboa Dam is equipped with 30 emergency sirens to warn of a possible breach to the dam. Several sirens are set up near the base of the dam, and sirens are spaced out for 40 miles upstream to the town of Esperance. Four of the sirens were damaged during Irene. Nearly 8 months later, on May 9, 2012, testing was done for the first time to ensure that the sirens were in working order.

Four USGS gauges on the Schoharie Creek were active during Tropical Storm Irene: USGS gauge #01351500 at Burtonsville, #01350355 at Breakabeen, #01350180 at North Blenheim, and #01350101 at Gilboa. USGS gauges #01350120 Platter Kill at Gilboa, NY, and #01350140 Mine Kill near North Blenheim are also active within the basin. The gauge at Burtonsville is the furthest downstream. Irene peaked at this location at 128,000 cfs. The FEMA FIS for Schoharie County predicts the 100-year flood event at the Burtonsville gauge to be 78,100 cfs and the 500-year event to be 109,000 cfs. Therefore, peak flows at Burtonsville during Tropical Storm Irene far surpassed the projected 100-year flood event and even exceeded the projected 500-year flood event. Table 3-3 presents estimated peak discharges at various locations along Schoharie Creek during Tropical Storm Irene.

TABLE 3-3
Estimated Peak Discharges
During Tropical Storm Irene (August 28, 2011)

Location	USGS Gauge No.	Drainage Area (sq. mi.)	Tropical Storm Irene Discharge (cfs)
Schoharie Creek at Burtonsville	01351500	886	128,000
Schoharie Creek at Breakabeen	01350355	444	134,000
Schoharie Creek at North Blenheim	01350180	358	119,000
Schoharie Creek at Gilboa	01350101	316	111,000

sq. mi. = square mile   cfs = cubic feet per second

According to a USGS report (2011), the flow on August 28, 2011, was nearly equal or exceeded the 0.2-percent (500-year) flood event for the Schoharie Creek stream gauges at Gilboa, North Blenheim, and Breakabeen. The report noted that FEMA FISs are not available for Burtonsville downstream to the mouth of the Schoharie Creek. In addition, USGS personnel surveyed 184 HWMs at 30 locations within the Schoharie basin following this flood event and found that the HWM elevations in the lower reaches of the basin exceeded published elevations for the 0.2-percent (500-year) flood event (Lumia et al., 2014).

Figure 3-2 presents annual peak flows recorded at USGS gauge #01351500 Schoharie Creek at Burtonsville, NY, between 1996 and 2014. According to a USGS report (2014), the HWM was surveyed in 184 locations along Schoharie Creek (upper and lower basins), and the HWM in the lower reaches of the basin exceeded those published by FEMA for their respective 0.2-percent (500-year) flood events. In addition, the USGS report noted that peak discharges exceeded their 1-percent (100-year) flood discharge at 25 stream gauges and their respective 0.2-percent (500-year) discharges at six sites in the Schoharie Creek basin.

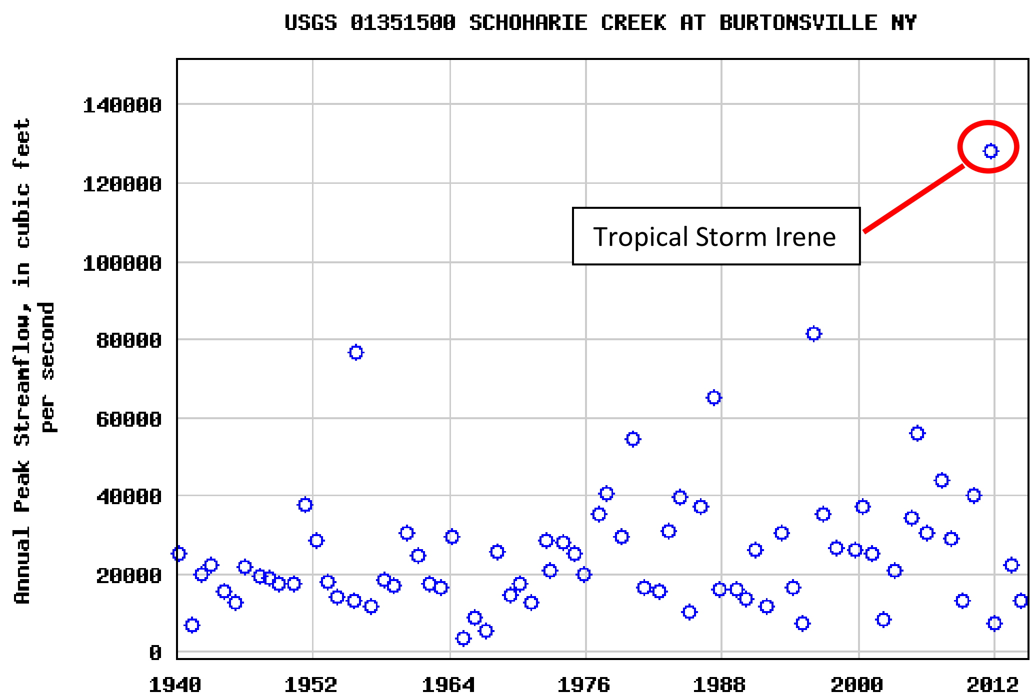


Figure 3-2
Annual Peak Discharge - USGS Gauge #01351500 at Burtonsville, NY

3.2 FEMA Mapping

FEMA FIRMs are available for various reaches of watercourses within the Schoharie watershed and depict the SFHA, which is the area inundated by flooding during the 100-year flood event. The maps also depict the FEMA-designated floodway, which is the stream channel and that portion of the adjacent floodplain that must remain open to permit passage of the base flood. Floodwaters are typically deepest and swiftest in the floodway, and anything in this area is in the greatest danger during a flood (FEMA, 2008). Maps showing the FEMA SFHA are included later in this report for the various focus areas.

4.0 FLOOD MITIGATION ANALYSIS AND ALTERNATIVES

A number of risk areas within the Lower Schoharie Creek watershed have been identified as being prone to flooding during severe rain events. Numerous alternatives were developed and assessed at each area where flooding is known to have caused extensive damage to homes and properties. Alternatives were assessed through the use of hydraulic modeling to determine their effectiveness. The sections below describe these alternatives and their results.

4.1 Analysis Approach

In order to develop hydraulic modeling to assess flood mitigation alternatives, MMI obtained effective FEMA HEC-RAS hydraulic models for areas of the watershed where they were available. Models were obtained from the NYSDEC, Floodplain Management Section, Bureau of Flood Protection and Dam Safety.

In order to develop hydraulic modeling in areas of the watershed where FEMA models were not available or to supplement existing FEMA models, survey was collected by MJ Engineering and Land Survey, P.C. Survey consisted of wet channel cross sections and hydraulic openings of bridges. Elevations of dry overbank areas were derived from LiDAR (Light Detection and Ranging) mapping.

Hydraulic analysis of the Lower Schoharie Creek watershed was conducted using the HEC-RAS computer program. The HEC-RAS software was written by the United States Army Corps of Engineers (USACE) Hydrologic Engineering Center and is considered to be the industry standard for riverine flood analysis. The model is used to compute water surface profiles for one-dimensional, steady-state, or time-varied flow. The system can accommodate a full network of channels, a dendritic system, or a single river reach. 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.

4.2 Mitigation Approaches

A number of mitigation approaches have been evaluated for the Lower Schoharie Creek watershed. These are introduced in a more global manner below and are evaluated in specific instances in the subsequent analysis.

4.2.1 Flood Preparedness

There are a number of ways in which home and business owners can minimize flood damages and ensure personal safety. The NFIP provides useful guidance on flood preparedness at www.FloodSmart.gov, or by calling the program at 1-888-379-9531. The following steps are recommended by the NFIP before, during, and after a flood:

Before a Flood:

1. Safeguard Possessions – Create a personal flood file containing information about all your possessions and keep it in a secure place such as a safe deposit box or waterproof container. This file should have the following items:

   - A copy of your insurance policies with your agent's contact information
   - A household inventory – For insurance purposes, be sure to keep a written and visual (i.e., videotaped or photographed) record of all major household items and valuables, even those stored in basements, attics, or garages. Create files that include serial numbers, and store receipts for major appliances and electronics. Have jewelry and artwork appraised.
   - Copies of all other critical documents including finance records or receipts for major purchases

2. Prepare

   - Make sure your sump pump is working, and then install a battery-operated backup in case of a power failure. Installing a water alarm will also let you know if water is accumulating in your basement.
   - Clear debris from gutters and downspouts.
   - Anchor any fuel tanks.
   - Raise your electrical components (switches, sockets, circuit breakers, and wiring) at least 12 inches above your home's projected flood elevation.
   - Place the furnace, water heater, washer, and dryer on cement blocks at least 12 inches above the projected flood elevation.
   - Move furniture, valuables, and important documents to a safe place.

3. Develop a Family Emergency Plan

   - Create a safety kit with drinking water, canned food, first aid, blankets, a radio, and a flashlight.
   - Post emergency telephone numbers by the phone and teach your children how to dial 911.
   - Plan and practice a flood evacuation route with your family. Know safe routes from home, work, and school that are on higher ground.
   - Ask an out-of-state relative or friend to be your emergency family contact.
   - Have a plan to protect your pets.

During a Flood:

- If flooding occurs, go to higher ground and avoid areas subject to flooding.
- Do not attempt to walk across flowing streams or drive through flooded roadways.
- If water rises in your home before you evacuate, go to the top floor, attic, or roof.
- Listen to a battery-operated radio for the latest storm information.
- Turn off all utilities at the main power switch and close the main gas valve if advised to do so.
- If you've come in contact with floodwaters, wash your hands with soap and disinfected water.

After a Flood:

- If your home has suffered damage, call your insurance agent to file a claim.
- Check for structural damage before reentering your home to avoid being trapped in a building collapse.
- Take photos of any floodwater in your home and save any damaged personal property.
- Make a list of damaged or lost items and include their purchase date and value with receipts, and place with the inventory you took prior to the flood. Some damaged items may require disposal, so keep photographs of these items.
- Keep power off until an electrician has inspected your system for safety.
- Boil water for drinking and food preparation until authorities tell you that your water supply is safe.
- Prevent mold by removing wet contents immediately.
- Wear gloves and boots to clean and disinfect. Wet items should be cleaned with a pine-oil cleanser and bleach, completely dried, and monitored for several days for any fungal growth and odors.

4.2.2 Sediment Management

Local representatives often report a sentiment that dredging will alleviate flooding within the Lower Schoharie Creek watershed and should be pursued. Dredging of the stream channel was evaluated as a flood mitigation technique within several of the focus areas. The need for dredging can be reduced by reducing the sediment load at its source and by improving sediment transport through reaches that are vulnerable to deposition. The two dam structures located in the upper watershed reduce sediment loading to the remaining system; however, sediments are likely to continue to be transported downstream to some extent regardless of what actions are taken to control the source in the upper reaches.

Dredging is often the first response to flooding. However, 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/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 the following:

- Situations where the channel is confined without space in which to laterally migrate
- For the purpose of infrastructure protection
- 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: