Saw Kill Watershed and Flood Mitigation Assessment - Final Report

NEIWPCC and NYSDEC Hudson River Estuary Program

MARCH 2018

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NEW YORK STATE OF OPPORTUNITY | Hudson River Estuary Program
A Program of the New York State Department of Environmental Conservation

NEIWPCC
New England Interstate Water Pollution Control Commission

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Acknowledgements

We would like to thank the following individuals and organizations for their contributions of time and effort in support of this project:

Megan Lung, Environmental Analyst, NEIWPCC; Hudson River Estuary Program
Elisa Chae, Source Water Specialist, New York State Water Resources Institute; Hudson River Estuary Program
Robert McKeon, Town Supervisor, Town of Red Hook
Harry Colgan, Town Board, Town of Red Hook
Theresa Burke, Highway Superintendent, Town of Red Hook
Laurie Husted, Chair, Town of Red Hook Conservation Advisory Council; Chief Sustainability Officer, Bard College Office of Sustainability
Susan Ellis, Town of Red Hook Conservation Advisory Council
Stephen Appenzeller, Town of Red Hook Conservation Advisory Council
Glen Butler, Highway Superintendent, Town of Milan
Jack Campisi, Town Council, Town of Milan
Erin Lefkowitz, Watershed Specialist, Student Conservation Association; Hudson River Estuary Program
Jan Borchert, Current Hydro
Joel Herm, Current Hydro
Gregg Swanze, Winnakee Land Trust
Jon Mickelson, Winnakee Land Trust
Nate Nardi-Cyrus, Scenic Hudson
Eli Dueker, Interim Leadership Team, Saw Kill Watershed Community

Document photos taken and provided by the Town of Red Hook, Inter-Fluve, and Fuss & O'Neill, Inc.

This document was prepared for the Hudson River Estuary Program, New York State Department of Environmental Conservation, with support from the New York State Environmental Protection Fund, in cooperation with the New England Interstate Water Pollution Control Commission. The viewpoints expressed here do not necessarily represent those of NEIWPCC or NYSDEC, nor does mention of trade names, commercial products, or causes constitute endorsement or recommendation for use.

Executive Summary

The NYSDEC Hudson River Estuary Program is seeking to help local decision-makers think more strategically about ways to utilize natural systems – floodplains, wetlands, forests, and green infrastructure – to provide more effective strategies to reduce flooding, while also benefitting the estuary ecosystem. The Saw Kill watershed has historically experienced flood damages along the main stem and some of its major tributaries. Public water supplies in the watershed are also susceptible to flooding-related impacts. There is significant local support by the watershed communities and other local stakeholders for a multi-benefit approach to address flooding.

This study examines the watershed holistically, through a land use GIS analysis, geomorphic assessment, rapid "windshield" river corridor inspection, and development of a hydraulic model, to evaluate flood risks at a watershed scale. Future increases in flood flows due to climate change were estimated using downscaled climate change model results and applied to the hydraulic model to examine the possible impacts. Ten conceptual site-specific projects are recommended as a result of this study:

1. Remove Annandale Dam.
2. Replace the NY-9G Bridge over the mainstem with a longer span.
3. Replace downstream Aspinwall Road Bridge and elevate the road approaches.
4. Consider removal or modification of Mill Road Dam.
5. Expand the riparian buffer and increase flood storage at Greig Farm.
6. Reactivate stream meanders downstream of Mill Road Dam.
7. Replace the US-9 Bridge with a longer span.
8. Replace and realign Echo Valley Road Bridge.
9. Reconstruct the channel upstream of Echo Valley Road Bridge with a stable bed and banks.
10. Remove the failed dam at Battenfeld Road.

Targeted recommendations are also provided for other parcels or areas of the watershed, including riparian restoration, floodplain restoration and reconnection, upgrade or replacement of undersized or aging culverts, and land conservation. The study also recommends additional measures that can be implemented throughout the Saw Kill watershed to further increase community resiliency and enhance habitat and water quality, such as land use regulatory/policy changes and local adoption of stream crossing design standards that promote stream continuity and flood resiliency.

Many of the study recommendations will have relatively small impacts on flood levels if performed individually, but the combined effects of these recommendations could significantly reduce existing flooding as well as anticipated increases in flooding as a result of climate change. Actions taken at a single river reach can have impacts throughout the watershed, and these impacts should be evaluated as projects are implemented.

Implementation of the flood mitigation recommendations identified in this report will require significant funding from grants and other sources, as well as collaboration between the watershed communities, county and state government, and landowners. The report identifies implementation priorities and recommended sources of funding for the site-specific and targeted project recommendations.

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1 Introduction

1.1 Project Background

The Saw Kill watershed ("watershed") is an approximately 26 square-mile area located in the mid-Hudson Valley region of New York State and the northwest portion of Dutchess County (*Appendix A, Figure 1*). The Saw Kill is a direct drainage tributary to the Hudson River; it flows approximately 16 miles in a westerly direction from its headwaters in the Town of Milan to the Hudson River via South Tivoli Bay. The watershed encompasses a large portion of the Town of Red Hook, the western portion of the Town of Milan, a small area within the northeast corner of the Town of Rhinebeck, and portions of the Village of Red Hook and the Hamlet of Annandale-on-Hudson (the location of Bard College).

The watershed has historically experienced riverine-related flood damages along the main stem of the Saw Kill and some of its major tributaries as a result of floodplain development and road crossings that serve as floodplain constrictions. Public water supplies in the watershed are also susceptible to flooding-related impacts. These supplies include municipal well fields in the Town and Village of Red Hook, portions of which are located within the 100-year floodplain, and the surface water intake for Bard College along the lower Saw Kill.

The New England Interstate Water Pollution Control Commission (NEIWPCC), in cooperation with the New York State Department of Environmental Conservation's (NYSDEC) Hudson River Estuary Program, selected the Saw Kill watershed for a grant-funded watershed flood mitigation assessment. The project was led by the consultant team of Fuss & O'Neill and Inter-Fluve, along with key project partners including the Town of Red Hook, Village of Red Hook, Town of Milan, Town of Rhinebeck, Saw Kill Watershed Community, and Bard College.

1.2 Project Objectives and Scope

The objectives of this project are to:

1. Identify areas prone to flooding and assess current and future flooding vulnerabilities in the Saw Kill watershed
2. Recommend measures to reduce flooding impacts to the watershed communities, including water supplies, through infrastructure (e.g., roads, bridges, culverts, buildings) and natural system solutions (e.g., conservation; restoration of habitat including riparian corridors, wetlands, and forests).

The project provides site-specific and targeted recommendations for the Saw Kill watershed, as well as regulatory, policy and planning recommendations for communities in the Saw Kill and other Hudson River Estuary watersheds to mitigate flooding through a multi-benefit approach. This project also builds upon important initiatives and studies completed or currently active in the watershed including:

- The previous FEMA Flood Insurance Study conducted on the lower Saw Kill
- The culvert and barriers study conducted by the Dutchess County Soil & Water Conservation District, NYS Water Resources Institute, NYSDEC HREP, and Cornell University

- The conservation framework Planning for Resilient, Connected Natural Areas & Habitats (2014)
- The Town of Red Hook's commitment as a Climate Smart Community (Pledge #7)
- Dam removal feasibility studies undertaken by Bard College and NYSDEC
- The NYSERDA-funded Climate Change Adaptation Research and Strategies, which is a proposed framework for evaluating how flood risk and vulnerability might change in local communities under future climate change (Abt Associates).

The scope of work for this study includes field reconnaissance, geomorphic assessment, hydrologic/hydraulic modeling of current and future flooding scenarios, analysis of flood mitigation alternatives, and identification of recommendations for mitigation of future flood hazards. An approved Quality Assurance Project Plan (QAPP) was developed to address field data collection, the use of existing data (i.e., secondary data), and modeling.

2 Areas Susceptible to Flooding

Areas susceptible to flooding in the Saw Kill watershed were determined through review of available FEMA FIS and flood hazard mapping (last updated 2012), information provided in the Dutchess County Hazard Mitigation Plan update (Tetra Tech, 2016), as well as interviews with municipal staff and residents. The areas identified through this review are summarized in *Table 1* and include 20 locations in the Towns of Red Hook and Milan, most of which are associated with the main stem of the Saw Kill. Details about flooding susceptibility and the damage caused by previous flood events are provided where known.

Appendix A, Figure 2 depicts identified areas susceptible to flooding as well as the areas along the Saw Kill that are located within FEMA regulatory flood zones. It should be noted that the FEMA analysis used to generate flood hazard mapping focused on only a portion of the main stem, and that flood hazard mapping has not been completed for the entire watershed. Furthermore, the hydrologic and hydraulic analysis that serves as the basis for the flood hazard mapping was completed in 1983.

Overall, the most significant flooding in the watershed has occurred along the lower portions of the Saw Kill, causing flooding of roadways, residential structures, and overtopping of bridges that cross the Saw Kill. The FEMA hydraulic analysis indicates that several bridges (River Road Bridge, Aspinwall Road Bridges, and the Echo Valley Road Bridge) overtop in the 10-year or 50-year up to the 500-year flood. The Linden Avenue Bridge (County Route 79) was reconstructed in 2016, providing greater hydraulic capacity than the previous bridge that was analyzed in the FEMA FIS hydraulic model. Based on anecdotal evidence, it is also believed that Echo Valley Road and the downstream Aspinwall Road Bridge have been repaired or partially reconstructed, but full documentation of the repairs was unavailable.

Table 1. Areas Susceptible to Flooding – Saw Kill Watershed

Description/Location	Stream	Municipality	Notes	Information Source
Shafer House on Bard Campus	Saw Kill	Red Hook	Flood waters severely damaged the building having flowed straight through the building. Historic structure is home to the Written Arts Program and Bard's literary journal, "Conjunctions," and has offices for faculty and staff and a seminar room that seats up to 15 people. Residential structure downstream of Shafer House suffers flooding.	Bard College
River Road Bridge (County)	Saw Kill	Red Hook	Overtops for 50-yr to 500-yr flood.	FEMA FIS
Annandale Road	Saw Kill	Red Hook	Annandale Road Triangle roadway flooding.	Red Hook DPW, County Hazard Mitigation Plan
State Route 9G Bridge (State)	Saw Kill	Red Hook	Causes backwater flooding of houses on Kelly Road and West Bard Road and Aspinwall Road. Roadway flooding and flood damage to single family residential structure.	FEMA FIS
West Bard Avenue	Saw Kill	Red Hook	Residential roadway flooding and flooding of single family residential structures.	Red Hook DPW
Aspinwall Bridge (Town)	Saw Kill	Red Hook	Overtops for 10-yr to 500-yr flood. Damaged during flooding events and Town frequently makes repairs after rain events.	FEMA FIS, County Hazard Mitigation Plan
Aspinwall Bridge (Town)	Saw Kill	Red Hook	Overtops for 10-yr to 500-yr flood. Damaged during flooding events and Town frequently makes repairs after rain events.	FEMA FIS
Linden Avenue Bridge (County)	Saw Kill	Red Hook	Overtops for 50-yr to 500-yr flood (bridge has been replaced with one of greater hydraulic capacity, so FIS does not reflect current condition).	FEMA FIS
Mill Road Dam (Private)	Saw Kill	Red Hook	Failed several times in past causing damage downstream including damage to town recreational park. Four bridges, primary and secondary roadways and their drainage systems, private properties, and the town water district are also at risk in the event of dam failure.	FEMA FIS, County Hazard Mitigation Plan
Mill Road Bridge (County)	Saw Kill	Red Hook	Low chord submerged in 50-yr and 100-yr flood, overtops for 500-yr flood.	FEMA FIS
US 9, Albany Post Road (State)	Saw Kill	Red Hook	Low chord submerged in 10-yr to 50-yr flood, overtops for 500-yr flood. Creates backwater that could affect Echo Road Bridge.	FEMA FIS
Echo Valley Road (County)	Saw Kill	Red Hook	Overtops for 10-yr to 500-yr flood.	FEMA FIS
Foam and Wash, State Route 199, Orlich Road	Saw Kill	Red Hook	Culvert becomes blocked with debris and causes flooding in this area of Town.	Red Hook DPW, County Hazard Mitigation Plan
State Route 199 Bridge (State)	Saw Kill Tributary	Red Hook	Low chord submerged in 500-yr flood, substantial head loss for all events. Oriole Mills Road flooding upstream but not clear if due to bridge.	FEMA FIS
Rock City Road	Saw Kill Tributary	Milan	Suffered damage in Hurricane Irene (2011).	Milan DPW
Old Mill Road	Saw Kill Tributary	Milan		Milan DPW
Battenfeld Road	Saw Kill Tributary	Milan	Suffered damage in Hurricane Irene (2011). Town of Milan replaced two 6-foot diameter culverts with a 14-foot corrugated metal bottomless arch culvert.	Milan DPW
Becker Hill Road (intersection with Battenfeld Road)	Saw Kill Tributary	Milan	Suffered damage in Hurricane Irene (2011). 6-foot diameter culvert. Past sediment issues downstream of this crossing.	Milan DPW
Mitchell Lane	Lakes Kill Tributary	Milan	2-foot diameter plastic culvert. Slightly overtopped during Irene.	Milan DPW
Shookville Road	Lakes Kill Tributary	Milan	Suffered damage in Hurricane Irene (2011). 4-foot wide arch culvert.	Milan DPW

In 2011, Hurricane Irene caused numerous road closures and several bridges were damaged in the Town of Red Hook. The Saw Kill was blocked by fallen trees, and tree and debris had to be removed. The outdoor roller hockey rink was damaged by floodwaters, along with the Town tennis courts. Bridges that suffered damaged include Aspinwall Road Bridges, Bank Bridge and Scism Road Bridge (Tetra Tech, 2016).

Roadway flooding has also occurred along several tributaries of the Saw Kill (NY-199, Rock City Road, Old Mill Road, Battenfeld Road, and Becker Hill Road) and Lakes Kill (Mitchell Lane and Shookville Road). During Hurricane Irene in 2011, numerous town roads in the Town of Milan were damaged by excessive runoff and floodwaters, including damage to undersized culverts and road shoulders. Multiple roads were closed, and basements were flooded. The Town replaced two 6-foot diameter culverts at Battenfeld Road with a 14-foot arch culvert following Irene (Tetra Tech, 2016).

3 Watershed Characteristics

3.1 Land Use/Land Cover

According to the 2011 National Land Cover Database (NLCD), the watershed is characterized by a mixture of forests, wetlands, farmland, and developed land cover (*Table 2*). Most of the developed land in the watershed is associated with residential land use. Medium and high-density residential land use is primarily located in the Village of Red Hook and nearby subdivisions, as well as Bard College in the lower portion of the watershed. Low-density residential land use and other low-intensity development, such as the Red Hook Golf Club, account for most of the developed land cover elsewhere in the watershed (*Appendix A, Figure 3*). Commercial areas in the watershed are limited and concentrated primarily in the Village of Red Hook. Forests and wetlands comprise more than 60% of the watershed, with the remaining 24% of the watershed devoted to hay and pasture-related agricultural uses. Within the area of the 100-year floodplain, 13.1% is developed, 18.5% is devoted to hay and pasture, while 64.5% is covered by forest, shrubland, or wetland.

Table 2. Land Cover Composition of the Saw Kill Watershed (NLCD 2011)

Land Cover	Percentage of Watershed
Developed	11.9
Open space	*6.4*
Low intensity	*3.7*
Medium intensity	*1.5*
High intensity	*0.2*
Forest	55.9
Wetland	7.2
Pasture	22.5
Cropland	1.2
Other	1.3

3.2 Geology and Soils

Soils in the watershed are a mix of dense till, ice-contact features, and stratified materials deposited by both glacial and post-glacial activity (NRCS, 2001). The upper portion of the watershed is mostly represented by till, while the lower part of the watershed shows evidence of ice contact features east of the village of Red Hook and lacustrine sand and gravel deposits (*Appendix A, Figure 4*). Such features are the result of the Red Hook Moraine, while the deposits show the influence of a post-glacial lake that spread north toward Albany behind the retreating Late Wisconsinan glacier (NRCS, 2001). Rock outcrops and soils shallow to bedrock or a confining layer are also prevalent throughout the watershed. The Saw Kill and Lakes Kill are underlain by recent alluvium, or flood-associated materials deposited sometime after glacial retreat, and outwash sand and gravel, deposited by glacial meltwater.

While much of the area of USDA prime and important agricultural soils has been converted to residential and commercial land uses in the southwestern part of Dutchess County, particularly Poughkeepsie, the prime agricultural soils in the Saw Kill watershed remain largely devoted to farming. The residents and the Town of Red Hook have aggressively supported protecting farmland from development through property acquisition and conservation easements (AKRF and Greenplan, 2014), as well as a municipal property transfer tax that funds farmland protection in the Town.

Soils are classified by USDA-NRCS into hydrologic soil groups based on their capacity to infiltrate precipitation or snowmelt. Those soils with lower infiltration capacity (groups C and D) produce runoff more readily than those with high infiltration capacity, which can contribute to flooding potential. In the Saw Kill watershed, approximately half of the soils by land area are in groups A and B (*Table 3)*, on which most development has occurred (*Appendix A, Figure 5*). More than one quarter of the watershed is categorized as group D soils. These D soils are largely in the upper reaches of the watershed, which may contribute to increased peak flows in the lower reaches of the Saw Kill.

Table 3. Hydrologic Soil Groups within the Saw Kill Watershed (NRCS, 2011)

NRCS Hydrologic Soil Group	Acres	Percent of Watershed
Water/Unspecified	272.2	1.6
A and A/D	1,664.3	9.9
B and B/D	6,796.2	40.4
C and C/D	3,271.9	19.5
D	4,805.1	28.6
Total	16,810	100

3.3 Public Water Supplies

The Saw Kill watershed is a source of drinking water for Bard College, the Town of Red Hook, and the Village of Red Hook. The Bard College surface water supply intake from the Saw Kill is located near the mouth of the river (*Appendix A, Figure 6*). Two separate wellfields (i.e., the land above and surrounding wells drilled into an aquifer) are the source of drinking water for the Town and Village of Red Hook. The recharge area for the Town wellfield extends from Rockefeller Lane south to below the Mill Road Dam. The Village wellfield extends from NY-199 south along US-9 to Barraco Boulevard and east beyond Metzger Road. Zoning restrictions to protect the aquifers from development and sources of potential contamination are in place within these recharge areas.

The Bard College surface water intake and the Town of Red Hook wellfield and associated recharge area are located within the mapped floodplain and regulatory floodway, making these water supplies susceptible to flood-related impacts. Floodwaters can contaminate public water supplies and/or damage public drinking water wellfields.

3.4 Road Stream Crossings and Dams

While road stream crossings (i.e., culverts and bridges) are an integral part of transportation infrastructure, inadequate or undersized crossings can be flooding and washout hazards. Inadequately designed, outdated, or undersized crossings can increase flooding of upstream and adjacent areas or have significant impacts to the transportation system. Across the U.S., culvert failures cost communities millions of dollars every year in property and infrastructure damages (MADER, 2012). Culverts can also serve as barriers to the passage of fish and other aquatic organisms along a river system, altering aquatic habitat and disrupting river and stream continuity.

Dams pose upstream flood hazards by backing up water during floods. Dams also present a hazard to downstream areas in the event of a breach or failure, which can result from aging infrastructure, insufficient maintenance and changes in upstream flow regimes. Dam failure can release large quantities of flow, sediment (sometimes contaminated), and debris and is, therefore, a threat to property, ecosystems, and public safety. Dams also fragment riverine systems, preventing the movement of fish and other aquatic life to feed, spawn, or migrate past the dams.

Multiple studies of stream crossings and dams in the Saw Kill watershed have recently been completed focusing on aquatic organism passability, hydraulic capacity, and dam safety. A 2017 report produced for the Town of Red Hook identified ten priority culverts targeted for upgrades or replacement to improve flood resiliency, habitat connectivity, and water quality (Crawford & Associates, 2017). This work builds on previous assessments by Cornell University, the NYSDEC Estuary Program, the New York State Water Resources Institute, and the Dutchess County Soil and Water Conservation District that categorized culverts in the watershed based on hydraulic capacity and aquatic passability (Walter et al., 2015). Of the 125 culverts in the Saw Kill watershed, 35 were identified as minor barriers, 74 were considered moderate barriers, and 16 were classified as major barriers (*Appendix A, Figure 7*). Work is ongoing to determine the hydraulic capacity of all culverts in the watershed, but Walter et al. (2015) noted that a majority of culverts evaluated were sized to accommodate a 25-year storm or smaller and that predicted changes in precipitation due to climate change will increase the number of undersized culverts. They further noted that linking hydraulic capacity with passability will be beneficial in improving overall watershed health. Feasibility studies for the Annandale and Mill Road dams have also been conducted (The Chazen Companies, 2016) evaluating the options to enhance stream continuity and flood resiliency through potential dam removal.

3.5 Wetlands and Forests

Combined with upland floodplains adjacent to rivers, streams, and man-made impoundments, wetlands play an important role in flood desynchronization and flood storage, in addition to many other ecological functions. The role that wetlands play in flood control, flood attenuation, and flood resiliency is complex and can be affected by many conditions, including antecedent water storage prior to flood events, groundwater hydrology, and the location of the wetlands within the watershed. Historical development of river corridors, floodplains, and upland areas adjacent to water bodies in the watershed has contributed to wetland loss and degradation. Future development pressure in the watershed has the potential to further reduce the effectiveness of natural and man-made wetland systems for mitigating flooding in the Saw Kill.

Wetlands and forests account for more than 60% of the land area in the Saw Kill watershed. Forested areas are primarily deciduous and wetlands are mainly wooded, rather than emergent herbaceous. The upper reaches of the Saw Kill, Lakes Kill, and their tributaries are largely forested, but roadways and associated development fragment forests, reducing habitat connectivity. Importantly, wetlands and forest cover represent 70% of the area within 200 feet of the Saw Kill, Lakes Kill, and their tributaries. Where wetlands and forests line the stream corridor, they can provide a buffer against the impacts to water quality arising from surrounding agricultural and residential land uses.

3.6 Critical Habitats

New York State identifies Important Areas of natural heritage, which are those lands and waters that support rare plant and animal species, rare or high-quality ecological communities, and ecosystem processes critical to maintaining these species and communities. Protecting these lands and waters are critical to ensuring the long-term viability of these areas.

Within the Saw Kill watershed, there are three main areas identified as Important Areas: the lower reaches of the Saw Kill from downstream of Linden Avenue to the confluence with the Hudson River, the forest and wetlands around Lakes Kill and its tributary along Turkey Hill Road from Spring Lakes to the confluence with Saw Kill, and much of the area around the Saw Kill within the Town of Milan.

The long-term viability of these individual areas is also impacted by their connectivity to each other. To that end, the Town of Red Hook participated in a pilot project that identified priority areas for conservation to ensure habitat connectivity. Five priority areas around the principal development centers in Red Hook were identified as likely pathways for migration and movement among critical habitats (AKRF, 2014). One of these priority areas overlaps part of the lower Saw Kill Important Area.

3.7 Open Space

Open space protection provides the permanent preservation of lands in a watershed by limiting development and impervious coverage, preserving the integrity of floodplains and other lands critical to flood mitigation, preserving natural pollutant attenuation characteristics, and supporting other planning objectives such as farmland preservation, community preservation, and passive recreation. Open space planning aimed at acquiring or protecting vulnerable land in river corridors and floodplains can be an effective approach for enhancing flood resiliency.

Three primary organizations are involved in conservation and protection of land in the Saw Kill watershed: the Dutchess Land Conservancy (DLC), the Scenic Hudson, and the Winnakee Land Trust (WLT). These organizations have conserved more than 2,800 acres of farmland and forest in and around the watershed, including along several segments of the Saw Kill through conservation easements (Figure 8).Within the area of the mapped 100-year floodplain, 28% is protected. Target areas for conservation have largely focused on farmland preservation through land trusts and municipal programs, though significant tracts of forest and wetlands have also received protection (*Table 4*).

Table 4. Summary of Protected Open Space in the Saw Kill Watershed

Land Cover	Protected Open Space (acres)	Unprotected Land (acres)	Percent of Land as Protected Open Space
Developed	64	1,948	3.3
Forest	819	7,907	9.4
Wetland	216	995	17.8
Pasture	647	3,119	17.2
Cropland	44	161	21.4
Other	100	696	11.2
Total (Watershed)	1,760	14,826	10.5

Parts of the Important Areas in the lower reaches of the Saw Kill and around the Lakes Kill are already protected by existing conservation easements. The remaining areas are currently undeveloped, consisting of either forest or wetlands, but remain legally unprotected.

Open space in the watershed is protected primarily through conservation easements. This mechanism of protection is common among land conservation organizations, especially related to agricultural land. Enforcement of the easement conditions in the long-term can be a challenge especially relating to conveyance, without more than one conservation easement holder.

4 Hydraulic Assessment

4.1 Field Assessment Methods

Fuss & O'Neill conducted a field assessment of priority flood locations within the watershed on July 25-26, 2017 to support the development of a hydraulic model of the Saw Kill and alternative flood mitigation approaches. The field assessment focused on areas of documented flood damages listed in *Table 1*, and areas with infrastructure that may be vulnerable to increased flows under future climate or land use change. A second, supplemental site visit was made on September 21 and 22, 2017. Specific data collection objectives of the assessment included:

- Field confirmation of existing hydraulic section data.
- Collection of new survey data where channel, stream corridor, or floodplain geometry, including road-stream crossings, appears to have changed or where more detail is needed.

Seven bridges were selected based on their location within the watershed study area, their apparent impact on flood elevations as shown in the FEMA FIS (Federal Emergency Management Agency, 2012), and the importance of the road as a traffic route (e.g., state and county routes were prioritized over local or private routes because they are likely to carry a greater volume of traffic and to be used more frequently by emergency vehicles. These bridges are referred to as "priority bridges" for the purposes of this study and their characteristics are summarized in *Table 5*.

A survey scope and Trimble Geo 7X GPS were used to conduct limited topographic survey within the stream channel below road-stream crossings at locations where conditions appeared to have changed compared to existing data or where there was evidence of scour or aggradation at priority bridge crossings. Benchmarks were not available in the field, so topographic survey data could not be directly referenced to a datum. Instead, additional elevations were measured at road approaches that would be well-characterized by available LiDAR data. In some locations, GPS signal was inadequate to determine location with an accuracy of at least 1 meter; where this occurred, the locations of elevation readings at the road approaches were visually located and are approximate.

Where possible, limited site survey was conducted upstream and downstream of each priority bridge, and bridge span and height was determined. Busy traffic conditions prevented access to the NY-9G bridge, and limited survey to only one side of the bridge at River Road, Aspinwall Road (downstream crossing), Mill Road, and NY-199 Bridges. These bridges were also assessed during later phases of the project using supplemental information from various sources, including the FEMA 2012 FIS and any plans available from state, county, and local government agencies.

At other locations, visual observations were made of landscape characteristics and infrastructure that may impact flood risk within the watershed. These observations were documented through photographs and handwritten notes. Measurements were taken where access was available, to confirm bridge or culvert opening sizes.

4.2 Field Assessment Findings

Multiple locations were noted where stream crossing and drainage infrastructure has been updated or replaced, which may impact flood risk in the watershed. Structures that appear to have been updated or replaced include:

- The Linden Avenue Bridge has been reconstructed.
- The Rock City Road Bridge over the Saw Kill main stem and a nearby bridge on the same road over a tributary both appear to be recently reconstructed or repaired.
- The NY-199 Bridge in Rock City has been recently reconstructed.
- The Mitchell Road crossing appears to have been recently reconstructed with a new 30-inch diameter corrugated metal culvert and a flared HDPE outlet.
- A crossing on Battenfeld Road has been upgraded to a 14-foot corrugated metal bottomless arch culvert.
- The downstream Aspinwall Road Bridge is commonly repaired after rainfall events.

The field investigation included measurement of bridge spans and heights. *Table 5* summarizes the bridge measurements collected.

Table 5. Summary of Priority Bridge Data

Road Name	Local, County, or State Road	Bridge Identification Number	Number of Spans	Total Combined Span Length (ft)	Functional Hydraulic Span Length (ft)	Constricting Opening Height (ft)
River Road (County Route 103)	County	3343710	2	84.0	72.7	9.0
NY-9G	State	1006440	1	89.0[1]	86.0	9.0
Aspinwall Road (downstream crossing)	Local	2262850	1	26.0	26.0	5.1
Linden Avenue (County Route 79)	County	3343730	1	65.0	62.8	8.0
Mill Road	County	3343720	1	85.0	85.0	12.3
Albany Post Road (US-9)	State	1005370	1	45.0	39.0	10.4
NY-199	State	1040020	1	37.0	32.0	9.6

[1]Field crew unable to access bridge due to high traffic volume; measurement taken from 1985 bridge plans.

In addition to the bridges listed in *Table 5*, other structures were observed throughout the watershed with the potential to impact flood risk by increasing water surface elevations during flood events. These include the following structures:

- An abandoned dam along Battenfeld Road, north of the intersection of Battenfeld Road with Shookville Road, which appears to be partially breached. The current size of the impoundment behind this structure is unknown.
- The Mill Road Dam, a privately-owned dam with a large impoundment. Significant damage to the dam owner's property during Irene appears to have been caused by the overtopping of the dam abutments. Information is available for this dam from a recent engineering feasibility study (The Chazen Companies, 2016).
- A small concrete dam, possibly breached, upstream of Rock City Road.
- A dam which could not be accessed, upstream of Rock City Road and the aforementioned small concrete dam.
- An undersized culvert at West Bard Avenue which creates backwater flooding of West Bard Avenue and single family residential structures upstream of the culvert

- The Annandale Dam, which is a priority structure in the hydraulic assessment phase of this project, was observed but no measurements were taken, as there is sufficient engineering information to incorporate this structure into the hydraulic model, including an Engineering Assessment completed in 2015 by Brinnier and Larios, P.C.

The intersection of Annandale Road and River Road known as the "Annandale Triangle", which has reportedly experienced significant flooding, was visually observed to evaluate potential factors associated with flooding in this area. The following observations were noted:

- No catch basins were observed on Annandale Road or the other roads near the Annandale Triangle, and this, in addition to analysis of the local topography, suggests storm runoff from the surrounding slopes is not the direct cause of flooding in this area.

- The large culvert under NY-9G likely allows the Saw Kill to "short circuit" during high flows, when the Saw Kill overtops its banks at Kelly Road. This overflow appears to flow west along the north side of Kelly Road, through the aforementioned culvert, and enters a low-lying wooded area. It is assumed that the flow then emerges from this wooded area at the east side of the Annandale Triangle, where it flows over the Annandale Triangle and two of its bounding roads and back into the Saw Kill at the western side of the triangle.

4.3 Hydraulic Analysis Methods

A steady-state[1] HEC-RAS hydraulic model was developed in GeoHECRAS (using HEC-RAS version 5.0.3) for the main stem of the Saw Kill, extending from the NY-199 Bridge (near Orlich Road) to immediately downstream of the Bard College drinking water intake. Two separate models were developed – one for existing conditions and another representing future conditions under a climate change scenario. Areas of detailed analysis within the model focused on areas that have experienced flood damages. In particular, the analysis focused on impacts associated with the Annandale Dam and seven bridges that have experienced flooding based on the 2012 FEMA Flood Insurance Study (FIS), information provided in the Dutchess County Hazard Mitigation Plan update, and interviews with municipal staff and residents. It was determined that the Mill Road Dam should also be considered a priority location for the analysis, as it appears to have extensive backwater effects based on the flood profile presented in the FIS.

Stream geometry and bridge and dam geometry data were incorporated into the model from available primary and secondary data sources including:

- A digital elevation model (DEM) developed from Light Detection and Ranging (LiDAR) data collected in 2014 was obtained from the Dutchess County Office of Central & Information Services (OCIS). The metadata indicates that the data is suitable for 2-foot contour generation, although the data is provisional and subject to revision.

[1] Steady-state refers to the condition where flow does not change over time (also referred to as "steady flow").

- A FEMA Flood Insurance Study (FIS) published in 2012 provided flow and water surface profile data for the Saw Kill. The hydraulic model that was used to generate the water surface elevations presented in the FIS was developed in 1983 using HEC-2 and was not available in digital format; therefore, this data could not be directly incorporated into the existing conditions HEC-RAS model developed for this study. Instead, the data was used as an initial guide to focus field assessment efforts and model development.

- Field assessments were conducted by Fuss & O'Neill staff in July and September 2017, during which the priority sites were assessed and stream transects were measured. Additional field reconnaissance was conducted in November 2017. As the transects and other elevations were measured without the benefit of horizontal or vertical controls, these values were entered into the model by comparing the measurements taken to specific fixed points in the LiDAR and FIS data described above, such as roadway elevations.

- Bridge plans, inspection reports, hydraulic vulnerability analyses, and related information obtained from Dutchess County, the State of New York, and the Town of Red Hook were used in the model development process. Plans were available for all public bridges, but were of varying legibility, completeness, age, and datum. Inspection reports were available for all public bridges except the recently replaced Linden Avenue Bridge, and hydraulic summaries were available for only some of the bridges.

- Survey data of the Annandale Dam impoundment gathered by Inter-Fluve during a September 2017 field visit[2], as documented in the geomorphic assessment report in *Appendix E*.

- Survey data of the Annandale Dam gathered by Brinnier & Larios, P.C. in July 2015.

Upon comparison of the LiDAR data to field data gathered by Fuss & O'Neill at the bridges, and to the profile presented in the 2012 FIS, it became evident that the LiDAR data within the stream channel represented an elevation that was higher than that of the actual stream bottom, most likely due to errors resulting from the presence of trees in the riparian area, and also due to the reflection of the LiDAR signal by the water surface, rather than the channel bottom. If left uncorrected, this would result in an overly conservative model, i.e., the model would likely predict higher flood elevations for a given flood flow than would actually occur. The stream bottom in the model was lowered uniformly by 4.9 feet, the average difference between the lowest point in the LiDAR within the channel at each bridge location and the lowest streambed elevation measured in the field (or in the absence of field measurements, from available bridge plans). The resulting streambed elevations were generally within one foot of the elevations in the FIS streambed profile, indicating that the template cut resulted in an acceptable representation of streambed elevations within the model.

In developing the model, a few simplifying assumptions were made regarding two relief culverts that were discovered beneath NY-9G, one immediately north of the NY-9G Bridge that was 2.5 feet in diameter, and one approximately 400 feet to the south of the bridge which was 2 feet high x 3.5 feet wide. These culverts were omitted from the existing conditions model as they convey a negligible

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[2] A field visit was conducted on September 22-23, 2017 to assess Annandale Dam on behalf of Bard College Office of Sustainability.

amount of flow relative to that conveyed by the bridge, and their inclusion tends to destabilize the model, causing errors in the modeled water surface elevations (WSEs) at the bridge.

4.4 Hydrologic Data – Existing Conditions

The Saw Kill is currently an ungauged stream, having had an operable stream gage (USGS 01364800 Saw Kill at Red Hook NY) only during the period 1960-1966. Given the limited stream gage data for the watershed, flood flow values reported in the 2012 FIS were used as input flow values at two locations within the HEC-RAS model (*Table 6*). The watershed area ratio method was used to estimate flood flows at a third location (Annandale Dam), where flood flows were not reported in the FIS. Flood flows at Annandale Dam were estimated from flood flows reported in the FIS at an upstream location (Linden Avenue Bridge) and a downstream location (confluence of the Hudson River with the Saw Kill). The resulting flood flow estimates were averaged to generate a final flood flow estimate for Annandale Dam (*Table 1*). The flood flows listed in *Table 6* were used in the existing conditions HEC-RAS model.

Table 6. Summary of Flood Flows Used in the Existing Conditions HEC-RAS Model

River Station	Location of Nearest Infrastructure	10-Year Flood Flow (cfs)	50-Year Flood Flow (cfs)	100-Year Flood Flow (cfs)	Source
R.S. 36813.7	**NY-199 Bridge**	1,480	2,560	3,300	FEMA, 2012
R.S. 18256.2	**Linden Avenue Bridge**	1,730	3,020	3,890	
R.S. 2726.3	**Annandale Dam**	2,036	3,564	4,593	Average of two estimates developed from applying the Watershed Drainage Area Ratio method to data from upstream and downstream locations provided in FEMA, 2012

4.5 Hydraulic Model Results – Existing Conditions

Table 7 summarizes the depth of overtopping (defined as the difference between the water surface elevation during the flood, and the top elevation of the given structure) at each of the seven priority bridges, the Annandale and Mill Road Dams, and other known flooding locations, during the 10-, 50-, and 100-year floods, under existing conditions. The modeled inundation area is shown on maps provided in *Appendix B* and the modeled flood profiles are included as *Appendix C*.

Under current conditions, the River Road and Aspinwall Road (downstream crossing, near West Bard Avenue) bridges are clearly undersized, overtopping during floods as small as the 50-year flood and the 10-year flood, respectively. The overtopping of these bridges results partially from the nature of the bridges' design. Many of the bridges on the Saw Kill are characterized by approaches that slope down toward the river, with the bridge built at the low point. In addition, they tend to constrict the channel into a cross section that is narrower than reaches upstream or downstream, causing backwater behind the bridge under high flow conditions as well as increased flow velocities within the bridge opening itself, as demonstrated in the photographs of the downstream Aspinwall Road Bridge in *Figure 1*. The

Linden Avenue Bridge may still face risk of overtopping during the 100-year flood, based on model results. This is unexpected, as the bridge has recently been reconstructed, and should be sized to convey the 100-year flood.

Figure 1. Photographs of the downstream Aspinwall Road Bridge. The relatively narrow bridge opening and limited vertical clearance constrict streamflow during high flow conditions.

While the four other priority bridges (US-9, NY-9G, NY-199, and Mill Road bridges) are not predicted to overtop during the 100-year flood, all of these bridges create a backwater condition during the 100-year flood, indicating that they reduce the flow capacity of the channel. This backwater effect can be seen in the profiles in *Appendix C*, where the slope of the water surface profile is less than that of the streambed profile upstream of these structures. The backwater behind these structures, and behind the Annandale and Mill Road Dams, contributes to greater flooding upstream of these structures. The backwater flooding behind the Annandale Dam and NY-9G Bridge is of particular concern, as the inundated areas upstream of these structures include residential properties. The inundation map provided in *Appendix B* indicates that multiple residential properties are inundated by the backwater that is created by one or both of these structures.

It should also be noted that the crest of the Annandale Dam is predicted to overtop during the 50- and 100-year floods, raising concerns about its stability. Further, the abutments at either end of the dam are lower in elevation than the dam crest, and, therefore, will overtop before the dam crest, and during smaller floods than would overtop the dam crest. The impacts of dam failure are currently unknown; however, another study being conducted by Fuss & O'Neill focuses on the stability of the Annandale Dam and the impacts of a possible dam breach, and will help inform future decisions regarding the Annandale Dam.

Based on the existing conditions hydraulic model results, the following locations of concern are also expected to be impacted by flood flows:

- **Bard Campus Surface Water Intake:** The intake structure and appurtenant structures and equipment will be submerged during the 10-year flood and larger floods; smaller floods may also impact this structure due to its low elevation relative to the river

- **Private Residence at 21 Cedar Hill Road:** The first floor (the lowest residential level) of the structure is elevated, while the foundation of the structure is exposed with a 3-foot drop from the cellar door to the cellar floor. Therefore, while the basement and surrounding gardens are expected to be impacted by the 50- and 100-year floods, the first floor is not expected to experience flooding during the 10-, 50-, or 100-year event.

- **Schafer House:** The floodwall adjacent to the river is predicted to overtop during the 50- and 100- floods. The first floor of the house, located below the top elevation of the floodwall, is also expected to be inundated. The 10-year flood is not predicted to overtop the floodwall; if the floodwall was absent, the 10-year flood would inundate the basement of the structure but not the first floor.

- **Annandale Triangle:** This area appears vulnerable during the 10-, 50-, and 100-year floods.

- **Annandale Hotel:** The basement of the structure, which current houses Bard College offices, may be impacted by certain floods, especially the 100-year flood.

- **Bard-owned buildings at 1250 and 1252 River Road:** The first floor of 1250 River Road is not predicted to flood during any floods assessed, but the basement may be affected. The first floor of 1252 River Road is predicted to flood during the 100-year flood, and the basement may be affected by smaller floods. These structures appear to be residential.

- **Town of Red Hook Well Intake:** Under existing conditions, the well intake is predicted to be overtopped during the 100-year floods, but not during the 10- or 50-year flood. However, the model indicates that during the 50- and 100-year floods, water elevations will be within a few feet of the intake elevation. Inundation may impact well operation and/or well water quality. The diversion channel from the river to the pond adjacent to the well intake is predicted to convey flow during all modeled floods. In addition, the well field (the area contributing groundwater to the well) is distributed both upstream and downstream of the Mill Road Dam, across both banks of the Saw Kill, and inundation depths in the well field will therefore vary depending on the specific location within the well field. Some areas are unlikely to be inundated by floods, while areas near the river may be inundated by several feet of water during high flows.

- **Village of Red Hook Well Intake:** The Village well intake and contributing well field is located outside of the inundation areas for the modeled floods.

Table 7. Depth of Overtopping at Notable Structures Under Existing Conditions

Location	Overtopping Measured From	Depth of Overtopping (feet)		
		10-Year Flood	50-Year Flood	100-Year Flood
Bard College Surface Water Intake R.S. 95.8	Top of intake structure	2.4	3.9	4.7
Private Residence at 21 Cedar Hill Road R.S. 1763.4	Basement threshold	--	1.3	2.2

Table 7. Depth of Overtopping at Notable Structures Under Existing Conditions

Location	Overtopping Measured From	Depth of Overtopping (feet)		
		10-Year Flood	50-Year Flood	100-Year Flood
Schafer House on Bard Campus R.S. 1999.5	First floor	--	1.8	2.7
River Road (County Route 103) Bridge R.S. 2824.9	Top deck of bridge	--	1.6	3.0
Annandale Dam R.S. 2986.6	Dam crest	--	1.3	1.6
NY-9G Bridge R.S. 5568.5	Top deck of bridge	--	--	--
Aspinwall Road Bridge (downstream crossing) R.S. 8370.7	Top deck of bridge	1.7	2.9	3.3
Aspinwall Road Bridge (upstream crossing) R.S. 10506.2	Top deck of bridge	2.1	3.2	3.9
Linden Avenue (County Route 79) Bridge R.S. 18256.2	Top deck of bridge	--	--	1.5
Mill Road Dam R.S. 21858.0	Dam Training Walls	--	--	--
Town of Red Hook Well Intake R.S. 20881.7 to 20243.5	Ground Elevation at Well Field	--	--	0.6-0.9
Mill Road Bridge R.S. 22608.5	Top deck of bridge	--	--	--
Albany Post Road (US-9) Bridge R.S. 28816.7	Top deck of bridge	--	--	--
Echo Valley Road Bridge R.S. 32003.3	Top deck of bridge	--	1.3	1.9
NY-199 Bridge R.S. 36771.4	Top deck of bridge	--	--	--

4.6 Comparison of Existing Conditions and FEMA Flood Insurance Study Findings

The WSEs generated by the HEC-RAS model described above were compared with the WSEs presented in the FEMA FIS, which are based on a hydraulic model developed in the early 1980s. With a few exceptions, most of the WSEs produced by the HEC-RAS model at these points are within two feet of the elevations shown on the flood profiles presented in the FIS.

The hydraulic analysis used to develop the FIS flood profile and mapping was completed in 1983 and has not been updated since. In the time since the FIS flood profiles were developed, changes in the watershed, such as development of land from agricultural land and forests to residential, industrial, and institutional land use types; increases in impervious area; and natural and anthropogenic changes to the geometry of the stream itself, have likely occurred. The geomorphic assessment completed by Inter-Fluve supports the hypothesis that the streambed has aggraded, or risen in elevation, due to sediment deposits over time, which would generally result in the higher flood elevations. This may explain why flood elevations generated by the HEC-RAS model are slightly higher than those presented in the FIS at the bridges and dams downstream of Mill Road Dam.

In addition, repairs and alterations have been made to in-stream structures since the FIS was completed, including, as noted above. Other structures may also have been altered during the same period, but documentation of such changes was not available to us at the writing of this memorandum. Such repairs can have a significant impact on flood elevations; for example, it is possible that the replacement the Linden Avenue Bridge with a new bridge of a larger span now allows flow to pass more efficiently downstream, reducing WSEs upstream but causing higher WSEs downstream of the bridge during high flows.

4.7 Hydrologic Data – Future Climate Change Scenario

Both mean and extreme precipitation in the Northeast has increased during the last century, with the highest number of extreme events occurring over the last decade. Continued increases in frequency and intensity of extreme precipitation events are projected (Frankson, et al., 2017). According to the National Climate Assessment, "The Northeast has experienced a greater increase in extreme precipitation over the past few decades than any other region in the United States; between 1958 and 2010, the Northeast saw a 74% percent increase in the amount of precipitation falling in very heavy events" (Melillo, Richmond, T.C., & Yohe, G.W., 2014). Rainfall in the region is expected to continue to increase due to climate change, which is expected to increase the risk of river-related flooding. Bridges, roads, and dams will be more susceptible to flood damage because of more severe storms and heavy rainfall.

The existing conditions HEC-RAS model was used to evaluate the potential increases in flood water surface elevations and inundation areas under a future climate change scenario. Future peak flood flows were estimated using the *Application of Flood Regression and Climate Change Scenarios to Explore Estimates of Future Peak Flows* web-based application Version 1.5 ("Climate Change Application") developed by the United States Geological Survey (USGS) for New York State (Burns et al., 2015). The application determines peak flood flows by applying one of two available emissions scenarios (a moderate emissions scenario and a high-emissions scenario) to five different downscaled climate change models over three different time periods (2025-2049, 2050-2074, and 2075-2099). The resulting predicted precipitation amounts are used as inputs to the regression equations used in Streamstats to produce peak flow values associated with these future conditions. In addition, the web tool calculates existing conditions peak flow values using the standard USGS Streamstats tool, and then calculates the percent change between the future and existing conditions peak flow values.

For the purposes of this analysis, the high-emissions scenario was selected since it reflects a "worst case scenario" for peak flows. The time period of 2075-2099 (i.e., end of century) was selected to consider a worst-case scenario and for consistency with the realistic lifespan (50-75 years) of most roadway and in-stream infrastructure. The potential future flood flows used in the future conditions HEC-RAS model and the percent increase in future flood flows relative to existing flood flows are summarized in *Table 8*. Estimated future flood flows for this climate change scenario are generally 22% to 27% higher than existing flood flow estimates for the 10- to 100-year flood return frequencies. The predicted future 100-year flood flows are greater than the existing 100-year flood flows but less than the existing 500-year flood flows.

Table 8. Summary of Flood Flows Used in the HEC-RAS Model Under a Future Climate Change Scenario

River Station	Location of Nearest Infrastructure	10-Year Flood Flow (cfs)	50-Year Flood Flow (cfs)	100-Year Flood Flow (cfs)	Citation
R.S. 36813.7	**NY-199 Bridge**	1,806 (+22%)	3,200 (+25%)	4,158 (+26%)	Values calculated by applying Mean Percent Increase determined by USGS Future Flows Web-Based Application to existing flood flow values provided in Table 1.
R.S. 18256.2	**Linden Avenue Bridge**	2,128 (+23%)	3,775 (+25%)	4,901 (+26%)	
R.S. 2726.3	**Annandale Dam**	2,504 (+23%)	4,491 (26%)	5,833 (+27%)	

The HEC-RAS model was run using these estimated future flood flows, to calculate the potential flood elevations under a climate change scenario, assuming no flood risk mitigation actions are taken.

4.8 Hydraulic Model Results – Future Climate Change Scenario

Table 9 summarizes the depth of overtopping of the same locations as *Table 7*. A map depicting the inundation areas for the 100-year flood, under both existing and future conditions, is provided in *Appendix B* and flood profiles are provided in *Appendix D*.

Table 9. Depth of Overtopping at Notable Structures under a Future Climate Change Scenario

Location	Overtopping Measured From	Depth of Overtopping (feet)		
		10-Year Flood	50-Year Flood	100-Year Flood
Bard College Surface Water Intake R.S. 95.8	Top of intake structure	2.9	4.6	5.5
Private Residence at 21 Cedar Hill Road R.S. 1763.4	Basement threshold	0.2	2.1	3.2
Schafer House on Bard Campus R.S. 1999.5	First Floor	0.1	2.6	3.7
River Road (County Route 103) Bridge R.S. 2824.9	Top deck of bridge	--	3.0	4.1

Table 9. Depth of Overtopping at Notable Structures under a Future Climate Change Scenario

Location	Overtopping Measured From	Depth of Overtopping (feet)		
		10-Year Flood	50-Year Flood	100-Year Flood
Annandale Dam R.S. 2986.6	Dam crest	0.7	1.6	1.9
NY-9G Bridge R.S. 5568.5	Top deck of bridge	--	--	--
Aspinwall Road Bridge (downstream crossing) R.S. 8370.7	Top deck of bridge	2.2	3.3	3.9
Aspinwall Road Bridge (upstream crossing) R.S. 10506.2	Top deck of bridge	2.4	3.3	3.9
Linden Avenue (County Route 79) Bridge R.S. 18256.2	Top deck of bridge	--	0.9	1.3
Mill Road Dam R.S. 21858.0	Dam training walls	--	--	--
Town of Red Hook Well Intake R.S. 20881.7 to 20243.5	Ground elevation at well intake	--	0.2-0.5	0.4-1.1
Mill Road Bridge R.S. 22608.5	Top deck of bridge	--	--	--
Albany Post Road (US-9) Bridge R.S. 28816.7	Top deck of bridge	--	--	--
Echo Valley Road Bridge R.S. 32003.3	Top deck of bridge	0.4	1.8	2.5
NY-199 Bridge R.S. 36771.4	Top deck of bridge	--	--	0.1

As indicated on the maps in *Appendix B,* the areas expected to be inundated during the 100-year flood will expand slightly, particularly along the Saw Kill tributaries, which tend to be low-lying relative to the surrounding terrain. The residential area upstream of the NY-9G Bridge would be impacted by the expansion of the inundation area under the climate change scenario considered.

In addition, the River Road Bridge, the Linden Avenue Bridge, both Aspinwall Road Bridges, which are modeled to overtop during the 100-year flood under existing conditions, would experience higher flood elevations, while the NY-9G, Mill Road, and US-9 Bridges would not be overtopped by floodwaters under the climate change scenario considered. The same structures which cause backwater flooding during the 100-year flood (the Annandale Dam, the Mill Road Dam, and the US-9, NY-9G, NY-199, Linden Avenue, and Mill Road Bridges) are expected to do so under the climate change scenario as well.

Flooding impacts are anticipated at additional structures of interest under the future climate change scenario, as described below:

- **Bard Campus Surface Water Intake:** While the intake structure is expected to flood during the 10-year flood and larger floods under existing conditions, the model indicates that flood depths will increase by approximately 6-12 inches (for modeled flood scenarios) at this location under future conditions. Smaller floods may also have greater impacts at this structure under the climate change scenario due to its low elevation relative to the river. Potential impacts include elevated turbidity and other potential contaminants, as well as structural damage to the intake structure resulting from debris carried by floodwaters.

- **Private Residence at 21 Cedar Hill Road:** The first floor of the structure is elevated relative to the Saw Kill and is not expected to flood during the future 10-, 50-, or 100-year. However, under future flow conditions, flood levels are expected to increase by 8-11 inches (for modeled flood scenarios) relative to existing flood elevations at this location. As a result, the basement is expected to be inundated during the 10-, 50-, and 100-year floods; the depth of overtopping at the basement threshold is expected to increase relative to existing conditions, as is the depth of flooding within the basement.

- **Schafer House:** The floodwall adjacent to the river is predicted to overtop during the 10-, 50- and 100-year floods, and the first floor of the house, located below the top elevation of the floodwall, is also expected to be inundated under future conditions.

- **Annandale Triangle:** This area, which is a known flooding location and is predicted to flood during 10-year and larger floods under existing conditions, is predicted to experience increases in inundation depths under the future climate change scenario.

- **Annandale Hotel:** The basement of the strucutre may be impacted by certain floods, especially the 100-year flood.

- **Bard-owned buildings at 1250 and 1252 River Road:** The first floor of 1250 River Road is predicted to flood during the 100-year flood, and the basement may be affected by smaller floods. The first floor of 1252 River Road is predicted to flood during the 50- and 100-year floods, and the basement may be affected by the 10-year flood.

- **Town of Red Hook Well Intake:** Under the future climate change scenario, flood depths are expected to increase at the site of the well intake, which may increase flood impacts on well operation or the quality of water withdrawn from the well. Inundation depths within both the diversion channel from the river to the pond adjacent to the intake, and the well field are also expected to increase, which may impact well water quality.

- **Village of Red Hook Well Intake:** The well intake and contributing well field remains outside of the modeled inundation areas for the modeled floods under the future climate change scenario.

It is important to note that the modeled climate change scenario represents only one possible future flood condition. This scenario is intended to provide a potential worst-case estimate of flooding during the future one percent chance flood. The 2075-2099 scenarios also corresponds to a time period when any new infrastructure built in the near future will reach its design life and become most vulnerable to flooding. Given the uncertainty in climate change projections, future increase in flooding may be smaller than predicted by this worst-case scenario, although the conservative nature of these projections may also account for potential contribution of future development in the watershed to flooding. The repair or replacement of infrastructure within the river corridor and other flood resiliency efforts, including future land use decision-making, should consider potential increases in flood elevations and expanded flood inundation areas as a result of climate change.

5 Geomorphic Assessment

A geomorphic assessment of the watershed was conducted by Inter-Fluve. The geomorphic assessment combined a review of existing data and a targeted reconnaissance-level field assessment to characterize geomorphic processes occurring in the watershed and to identify flood mitigation alternatives related to channel and floodplain geomorphology and function. A summary of Inter-Fluve's assessment is provided below. The full assessment report is provided as *Appendix E*.

- The channel and floodplain of the Saw Kill have been modified over the years by dredging, straightening, and clearing for agriculture, although riparian buffers have been re-established in many areas. The extent of forest cover in the watershed has increased significantly since the 1930s, when land was farmed right up to the river's edge in many places, based on a qualitative review of historical aerial photos.

- In general, the stream channel, where surveyed, appears to be relatively stable, and current channel form is likely to have been influenced by the land-use history of the watershed. Inspections of aerial photos from the 1930s and 1940s show relatively little planform change (i.e., change in the position or pattern of the river channel in map view) up to the present day, even within sinuous reaches (reaches with significant curvature).

- Because of the relatively low gradient of the lower reaches of the Saw Kill, small blockages or high spots on the channel bed cause a backwater effect, limiting in-stream habitat complexity and encouraging accumulation of fine sediment during low flows.

- During floods, the influence of small barriers is reduced, and the flood profile is instead dominated by larger features, including dams and bridges.

- The floodplain available for flood storage is limited in some places by terraces of glacially or alluvially derived material.

- Annandale Dam: Data collected for this study suggests that 7,000-10,000 cubic yards of fine sediment is stored in the impoundment and would be susceptible to mobilization if the dam is removed; the accumulation of these sediments limits habitat complexity in the impoundment.

- Upstream Aspinwall Road Bridge: The channel upstream of the bridge appears stable with no evidence of aggradation, incision, or ongoing bank erosion outside of the immediate vicinity of the bridge. A property owner has constructed a small dam of boulders and cobbles in this reach.

- Mill Road Dam: The reach downstream of the dam has been artificially straightened and dredged, with no floodplain access. A high-flow intake channel feeds a pond located adjacent to the Town of Red Hook well field. Aquatic habitat opportunities are limited in this reach.

- Greig Farm: The land adjoining the river is farmed right up to the narrow riparian buffer. There are some undercut banks and evidence of minor lateral erosion.

- Echo Valley Road: The owner of the property downstream of the bridge stated that he had lost land from erosion since the bridge was reconstructed on a skew. Beaver activity upstream of the bridge is currently impounding low flows.

- Battenfeld Road: A failed concrete dam constricts flow in the channel and impounds a small wetland.

The following recommendations were provided for consideration, and, in some cases, for further evaluation using the hydraulic model developed for this study:

- Remove artificial barriers or restrictions where possible. This may include dam removal, as well as bridge replacement and realignment.

- Vegetate active floodplains and restore natural river meanders to slow flood flows.

- Protect open spaces, increase floodplain storage in upstream areas, and confine future vulnerable development types to higher ground.

- Annandale Dam: Evaluate the removal of Annandale Dam to reduce flood risk to upstream properties and improve habitat complexity within the impoundment; in the event of removal, consider excavating and reusing impounded sediments on-site.

- Mill Road Dam: Re-activate the former meandering channel immediately downstream of the dam, to serve as the primary channel during low to medium flows, in order to slow flows, reconnect the floodplain, and improve the quality of in-stream habitat. Consider filling the existing high-flow connector channel and pond to improve the quality of pumped groundwater. Discuss option with affected landowners to better determine feasibility.

- Greig Farm: Consider increasing the riparian buffer by planting up to 15 acres to cover the 500-year floodplain on the farm's land, which is already protected by a partial conservation easement. Increase flood storage by regrading and planting upland areas and/or the existing 100-year floodplain to create additional forested floodplain at a lower elevation.

- Echo Valley Road: Investigate replacement and realignment of the bridge, as well as reconstruction of the upstream channel with stable bed and banks; remove obstructions upstream of the bridge that have resulted in channel adjustment.

These and other recommendations, in particular the site-specific recommendations, were considered as alternatives in *Section 6*, which includes evaluation of flood mitigation alternatives and modeling of the potential flood mitigation benefits of selected alternatives.

6 Flood Mitigation Alternatives Evaluation

Site-specific flood mitigation alternatives were identified based on the findings of the hydraulic and geomorphic assessments described in *Sections 4 and 5*, as well as discussion with stakeholders. These alternatives are intended to mitigate documented and modeled flooding impacts along the Saw Kill under existing and future climate change streamflow scenarios. The recommendations generated by this analysis are summarized in *Section 7.1* and in the conceptual recommendation figures provided in *Appendix F*. Other targeted and watershed-wide strategies, discussed in *Sections 7.2* and *7.3* respectively, were also considered to more broadly address flood-related issues throughout the watershed.

6.1 Evaluation Criteria

The site-specific flood mitigation alternatives that were identified in this study were evaluated for their overall effectiveness at reducing flood risk, general feasibility for implementation, and other related benefits, which are summarized in the *Appendix G*. Flood risk reduction benefits were evaluated quantitatively using the existing and future conditions HEC-RAS hydraulic model that was developed for the Saw Kill as part of this study. The model was used to predict whether the alternatives will increase or decrease flood water surface elevations, particularly in developed areas and at critical infrastructure such as bridges and dams. Flood mitigation alternatives were modeled by altering the geometry and characteristics of the stream channel, floodplain, and/or stream crossings to represent the alternatives selected for analysis. Some of the alternatives were evaluated qualitatively given the limitations of the HEC-RAS model and the scope of this study.

The site-specific alternatives were evaluated against other criteria, in addition to changes in flood elevations and associated flood risk. These other evaluation criteria included:

- Existing condition of the structure
- Potential for catastrophic failure of the structure and downstream impacts
- Ecological impacts/ecosystem services (positive and/or negative)
- Water quality impacts (positive and/or negative)
- Geomorphic impacts (positive and/or negative)
- Potential community support for the alternative and social impacts
- Potential alternative uses for the structures evaluated
- Potential sediment management concerns
- Potential impacts to public water supplies

Approximate order-of-magnitude cost ranges (considering both capital costs and operation and maintenance costs) were developed for each site-specific recommendation. Estimated cost ranges for recommended alternatives are summarized in *Appendix H*.

6.2 Site-Specific Analysis

The site-specific flood mitigation alternatives are discussed below by river reach, starting at Annandale Dam and proceeding upstream.

6.2.1 Reach #1: Annandale Dam Impoundment and Upstream Residential Area

Annandale Dam, owned by Bard College, is located upstream of the River Road Bridge and at the edge of a low-density residential and institutional area. Its original use was originally as a mill dam to provide mechanical power. It is currently an aesthetic feature on the campus; however the College is currently evaluating the feasibility of returning the dam to power production by installation of hydroelectric generating capacity. The dam impounds an area stretching upstream past the NY-9G Bridge and the residential neighborhood east of NY-9G. The backwater caused by this dam appears to be a factor in the flooding experienced at residences on West Bard Avenue. The NY-9G Bridge also appears to be a source of backwater flooding in upstream areas, based on initial modeling results. The bridge is described as a hydraulic constriction in a 2017 NYSDOT Hydraulic Summary, with the 100-year flood in pressure flow.

Alternative 1-1: Remove Annandale Dam

The full removal of the dam, including the removal of accumulated sediment from the main channel in the impoundment, was evaluated using the HEC-RAS hydraulic model by removing the dam structure and lowering the streambed elevations within the main stream channel to the elevation associated with the depth of refusal, presumed to be the historic armored stream bottom, based on measurements taken by Interfluve in September 2017.

The model results indicate that removing the dam will lower flood depths upstream of the dam by up to approximately 1 foot for the existing and future 10- to 100-year floods. Greater changes in flood depths are associated with more frequent storms (i.e. the 10-year storm) because flood water surface elevations for these smaller storms are closer to the top elevation of the dam structure, while larger, less frequent storms produce much higher flood elevations relative to the dam, limiting the structure's influence on elevations during larger floods.

Full removal of the Annandale Dam is predicted to reduce upstream flood elevations at locations up to 4,165 feet upstream of the dam (1,420 feet upstream of the NY-9G Bridge), including:

- The NY-9G Bridge:
  - Flood level reduction range from by 0.3 feet during the future 100-year flood to reductions as high as 1.2 feet during the existing 10-year flood
  - The frequency with which the bridge is subjected to pressure flow or overtopping will be reduced, but the bridge will still be under pressure flow during the existing and future 50- and 100-year floods, as it is under current conditions.

- The residence immediately upstream of the NY-9G Bridge – reductions of up to 1.1 feet during the existing 10-year flood and approximately 0.3 feet during the future 100-year flood.

- Along West Bard Road (a known location of frequent flooding) – reductions of up to 0.7-1.1 feet during the existing 10-year flood and approximately 0.2-0.3 feet during the future 100-year flood.

Full removal of the dam would also eliminate the risk of catastrophic failure of the structure and the associated potential impacts to structures downstream, based on the current hazard classification of the dam as a Class "B" (Significant Hazard). The hazard classification is currently being evaluated by Bard College as part of an engineering assessment that is required by the NYSDEC Dam Safety Section. Removal of the dam has a number of potential ecological benefits, including improving resident fish and American eel passage and riverine habitat.

Removing a dam can potentially affect flood elevations in downstream areas due to changes in hydrology and hydraulics associated with the dam removal. At the Annandale Dam, there will not be measureable impacts to peak flows (hydrology) due to dam removal because the dam provides minimal flood storage above the normal pool as compared to the volume of runoff expected from the full watershed. However, under existing conditions, the presence of the Annandale Dam causes flow to overtop NY-9G north of the bridge, flood the Annandale Triangle, and discharge back to the Saw Kill over River Road, thereby bypassing the River Road Bridge, during the existing 100-year flood and future 50- and 100-year floods. Removal of the dam will reduce the amount of flow overtopping NY-9G during these and other floods by providing more capacity for these flows within the main channel. This will result in flood risk reduction benefits to NY-9G and reduce the risk of traffic or emergency service interruptions and road washouts. However, this will also route more flow through the River Road Bridge and past the former Annandale Hotel. At the River Road Bridge (located approximately 200 feet downstream of the dam) flood levels are expected to remain unchanged for the existing and future 10-year floods and the existing 50-year flood and to increase by approximately:

- 0.6 feet during the existing 100-year flood,
- 0.5 feet during the future 50-year flood, and
- 1 foot during the future 100-year flood.

Along the parking lot at 1259 River Road (the former Annandale Hotel, a structure owned by Bard College), similar but slightly smaller increases in flood elevation are expected immediately downstream of the bridge, with the following increases in flood WSEs at the former Annandale Hotel:

- less than 0.3 feet during the existing 100-year flood,
- less than 0.3 feet during the future 50-year flood, and
- approximately 0.5 feet during the future 100-year flood.

These increases may also impact the structures at 1250 and 1252 River Road, with the following increases in flood WSEs:

- approximately 0.6 feet during the existing 100-year flood,
- approximately 0.5 feet during the future 50-year flood, and
- approximately 0.9 feet during the future 100-year flood.

In weighing these changes in flood elevations with the reduction in flood elevations farther upstream, it should be noted that:

- Overall, the predicted flood level reductions upstream are greater than the predicted flood elevation increases downstream.

- Reducing flood elevations during more frequent floods may have greater flood risk mitigation benefit overall than attempting to maintain existing flood elevations during less frequent floods such as the 100-year flood, which would be expected to cause significant damage even if flood elevations did not increase.

- Under current conditions, the River Road Bridge overtops during the existing 100-year flood and would overtop during the future 50- and 100-year floods. The downstream increases in flood elevation associated with removal of the Annandale Dam would not cause the River Road Bridge to overtop any more frequently than already occurs under existing flood conditions.

- NY-9G is classified as an Urban Major Collector, while River Road is classified as an Urban Local road. NY-9G is therefore considered the more critical route for traffic, commerce, and emergency services.

- If the portion of NY-9G north of the bridge (that currently overtops to allow flow to the Annandale Triangle) is elevated during a future project in order to further reduce the frequency of flooding, flood elevations at the River Road Bridge and former Annandale Hotel would rise regardless of whether the dam is removed. If the dam remains in place, elevating NY-9G also would increase the risk associated with the dam.

The predicted increase in flood elevations described above could be partially or wholly mitigated through some combination of the following alternatives:

- Removal of sediment in the impoundment, as discussed in *Management of Impounded Sediment*, below. The modeling analysis for *Alternative 1-1* does not account for removal of this additional sediment, which may increase available storage in the overbank area and floodplain.

- Excavation of additional storage and enhancement of the riparian buffer at the south end of the existing impoundment

- Floodplain terracing downstream of River Road Bridge, particularly on river left (on the bank opposite the former Annandale Hotel) which would provide the additional benefit of floodplain reconnection in this area.

Flood elevations are not expected to increase significantly at the Schafer House, the private residence at 21 Cedar Hill Road, or the Bard surface water intake as a result of the dam removal.

Some of the factors that may be considered by the dam owner, Bard College, if they are contemplating the removal of this dam could include:

- **Condition of the Structure:** The Annandale Dam is currently rated as "Unsound - Fair" by NYSDEC. In addition, an engineering report dated October 2015 indicated that the spillway does not provide adequate capacity to meet New York State Dam Safety criteria for the current

Class "B" (Intermediate Hazard) Classification. Significant repair work would be required to repair the dam to the degree required by state law.

- **Failure Risk:** All dams present some risk for catastrophic failure (i.e., the sudden breach or failure of the dam during a flood event, which can cause a wave of water and debris to be released over a short period of time and flow downstream, possibly resulting in further risk to human safety and infrastructure downstream). The previously referenced engineering report indicates that the dam is considered as posing an Intermediate Hazard potential to downstream areas; however it also alludes to the possibility that the Hazard Classification could be changed based on more detailed hydraulic analyses of a dam breach. The potential impact of a dam breach is currently being assessed by Bard College and Fuss & O'Neill through a separate project to develop dam breach flood inundation mapping. The only way to completely eliminate the risk associated with a catastrophic failure is to remove the dam.

- **Potential Alternative Uses of the Structure:** The Bard College Office of Sustainability is currently investigating the feasibility of returning the Annandale Dam to power generation by installation of hydroelectric power generating capability. The impoundment could also potentially be used for recreation or retrofitted to provide a small amount of flood storage. The latter would require further assessment using a linked hydrologic and hydraulic model to determine the amount of potential flood storage, although the potential benefit would likely be small.

- **Ecological and Water Quality Impacts of Removal:** Removal of the dam is expected to provide an array of ecological benefits. By impounding water and sediment, the dam has caused the impounded area of stream to become more homogenous, thereby providing less valuable habitat to aquatic wildlife. Impounded bodies of water also tend to have elevated temperatures and have lower dissolved oxygen concentrations than would be expected if the reach were free-flowing, leading to water quality concerns in the impoundment and in areas downstream where the warmed water is eventually released. The shallower depths and warmer water in the impoundment, coupled with nutrient loadings from the watershed and accumulated sediments, contributes further to oxygen depletion and growth of aquatic plants and algae in the impoundment. In addition, the presence of the dam prevents the movement of aquatic organisms upstream or downstream past the dam. Removal of the dam would improve water quality and restore aquatic organism passage in this reach of the river, as well as increase habitat complexity in the impoundment either naturally over time or through active restoration.

  Removal of the dam may also lower groundwater levels, with potential negative impacts on upstream wetlands. In addition, sediment in the impoundment has been colonized by wetland species, and may qualify for wetland protection. *Alternative 1-1* may require measures to protect valuable wetlands or provide on-site compensatory mitigation (potentially by regrading impounded sediment to lower wetland elevations).

- **Management of Impounded Sediment:** Data collected for this study suggests that 7,000-10,000 cubic yards of fine sediment is stored in the impoundment and would be susceptible to mobilization if the dam is removed. The potential release of contaminated sediments can have adverse downstream effects, and removal and disposal of contaminated sediments can significantly increase the cost of dam removal. A detailed sediment management plan is essential in any dam removal in order to mitigate potential impacts of a sediment release downstream. The Chazen Companies conducted a preliminary study in 2016 investigating the feasibility of removing Annandale Dam. The study found that the bulk of the sediments in the impoundment would qualify as Class A sediments and therefore may be suitable for on-site reuse if dredged. However, additional sediment analyses are required to adequately characterize the sediment and develop a sediment management plan. The analysis should include PCBs, which have previously been identified by Fuss & O'Neill in sediments impounded by Lower Saw Kill Dam, which is located downstream of the Annandale Dam.

Additional factors related to the feasibility of removing Annandale Dam are discussed further in The Chazen Companies (2016).

Alternative 1-2: Replace and Upgrade NY-9G Bridge

The current span of the NY-9G Bridge is 85 feet. NYSDEC recommends that new and replacement bridges be constructed with a span of 1.25 times the width of the stream channel bed, in order to safely pass flood flows and accommodate passage of fish, other aquatic and semi-aquatic organisms, and terrestrial wildlife. The HEC-RAS model was updated to reflect an increase in the span to approximately 147 feet (which is anticipated to exceed the NYSDEC recommendation) based on visual interpretation of aerial imagery and LiDAR data available for this reach.

The model indicates that an increase the bridge span by this extent will reduce flood elevations at the NY-9G Bridge by approximately 0.2-0.5 feet across all floods events analyzed. Although the bridge is not currently expected to overtop during floods up to the future 100-year flood (the largest flood analyzed herein), this reduction in flood elevations may slightly reduce risk to the bridge by reducing the frequency with which the bridge experiences pressure flow conditions (i.e., when the bottom edge of the bridge deck is submerged) For the modeled bridge replacement scenario, the predicted upstream extent of flood water surface elevation reductions is similar to the Annandale Dam removal alternative, extending up to 1,420 feet upstream of the NY-9G Bridge, but to a lesser degree. Reductions of up to approximately 0.6 feet are anticipated for the current and future 10-year flood in residential areas upstream of the bridge. Smaller reductions in upstream flood elevations are expected for larger floods. Similarly, flood elevations are expected to increase at the River Road Bridge and the Bard structures at 1250 and 1252 River Road by up to approximately 0.5 feet for the future 100-year flood (the largest flood event analyzed). Flood elevations are also expected to increase downstream of the River Road Bridge, but only by up to approximately 0.5 feet for the future 100-year flood. Within the Annandale Dam impoundment, flood elevations are expected to increase by up to approximately 0.9 feet (for the existing 100-year event), which could put additional strain on the dam if the NY-9G Bridge is replaced with a larger bridge and the dam remains in place.

Alternative 1-3: Remove Annandale Dam / Replace and Upgrade NY-9G Bridge

As increasing the span of the NY-9G Bridge could have negative impacts on the Annandale Dam during large flows, the combination of both alternatives was modeled in HEC-RAS using the same parameters described in *Alternatives 1-1* and *1-2*. The model indicates that the combination of removal of the dam and increasing the span of the NY-9G Bridge would result in greater flood elevation reductions in the Kelly Road neighborhood than either alternative alone, with flood water surface elevation reductions of up to 1.5 feet possible for the current 50-year flood event. Flood elevations in the Annandale Dam impoundment would also experience a smaller decrease than expected from dam removal alone, though the elimination of the risk of catastrophic failure and the other ecological and water quality benefits of dam removal would still be achieved.

At the River Road Bridge and the Bard structure at 1250 and 1252 River Road, flood elevations are expected to increase by approximately the same amount as the dam removal scenario alone (up to approximately 0.8 feet for the current 100-year flood). However, flood elevations downstream of the River Road Bridge would also experience greater increases than either alternative alone (up to a 2-foot increase for the future 100-year flood scenario), which may require flood mitigation as described under *Alternative 1-1*, complicate permitting and result in the need for additional bank stabilization. The increase in flood elevations could be partially or wholly addressed through some combination of the following alternatives:

- Removal of sediment in the impoundment, as discussed previously. The modeling analysis for *Alternative 1-1* does not account for removal of this additional sediment, which may increase available storage in the overbank area and floodplain.
- Floodplain terracing within the impoundment in the reach downstream of the NY-9G Bridge
- Excavation of additional storage and enhancement of the riparian buffer at the south end of the existing impoundment
- Floodplain terracing downstream of River Road bridge, particularly on river left (on the bank opposite the former Annandale Hotel) which would provide the additional benefit of floodplain reconnection in this area.

Water surface elevations are not expected to rise significantly at the Schafer House, the private residence at 21 Cedar Hill Road, or the Bard surface water intake under any of the modeled flood events for this combined alternative.

Refer to *Alterative 1-1* regarding additional considerations regarding the potential removal of the Annandale Dam, including current condition of the structure, potential environmental considerations, and potential alternative uses of the dam.

Alternative 1-4: Repurpose Annandale Dam Impoundment for Flood Control

This alternative involves the preemptive lowering of the Annandale Dam impoundment using the low level outlet structure or weir boards immediately prior to storms to provide additional flood storage in the impoundment. The run-of-river impoundment is small relative to the size of the watershed, and therefore provides limited flood storage even when empty. The anticipated flood mitigation benefits of this alternative are therefore believed to be minimal. This approach would require significant operation and maintenance, including monitoring of potential flood conditions, manual or automatic operation of the low level outlet prior to storms, either of which may come with significant costs over time, especially since the small storage capacity of the dam may require frequent operation of the low level outlet. In addition, periodic draining or drawdown of the impoundment would result in an unnatural flow regime that would negatively impact habitat and water quality in the Saw Kill as well as recreational use of the stream channel downstream of the dam. This alternative would also not address the risk of catastrophic failure of the dam and associated downstream impacts.

Alternative 1-5: Lengthen the Annandale Dam Spillway to Accommodate Greater Flows

The existing spillway measures 61 feet in length and is wider than the natural channel. Lengthening the spillway would increase flow capacity through the spillway, which is currently considered undersized based on the spillway analysis provided in the aforementioned engineering report (Brinnier & Larios, 2015). In fact, if the dam remains in place, the spillway capacity will have to be significantly increased in order to meet NYSDEC's dam safety design guidelines (NYSDEC, 1989). However, lengthening the spillway would also expand the area of potential downstream impacts, possibly leading to erosion of downstream soils, including soils around the River Road (County Route 103) Bridge and the parking lot immediately downstream. These potential impacts and the need for additional stabilization around the bridge and downstream parking lot would need to be investigated further. Lengthening the spillway also has the potential to decrease flood elevations upstream of the dam and to increase flood elevations at the River Road Bridge and downstream areas, for the same reasons described in *Alternative 1-1*, though this increase would likely be slightly less than expected for a full dam removal. No ecological or water quality benefits are anticipated from lengthening the spillway.

Alternative 1-6: Lower the Annandale Dam Spillway to Accommodate Greater Flows

Lowering the spillway would increase flow capacity through the spillway, which is currently undersized as stated above and will likely require an increase in capacity to meet state dam safety guidelines. A small increase in flood storage may be achieved by lowering the spillway (and thereby lowering upstream water surface elevations), but would likely provide minimal flood risk mitigation benefit due to the small volume of the impoundment relative to flood flows. Lowering the spillway also has the potential to decrease flood elevations upstream of the dam and to increase flood elevations at the River Road Bridge and downstream areas, for the same reasons described in *Alternative 1-1*, though this increase would likely be slightly less than expected for a full dam removal.

A similar alternative consists of retrofitting the existing spillway with a bottom-hinged spillway gate that would open by lowering as water surface elevations rise in the impoundment due to flood flows. The spillway gate would be automated and would respond to water level sensors that indicate the impoundment water level is beginning to rise. The gate would respond by opening to create greater flood conveyance capacity to keep the water surface elevation at the normal pool level. The wide-open position of the gate (lying down fully horizontal) would reflect a condition of complete removal of the spillway section of the dam and would provide associated flood conveyance capacity. This option would allow the normal pool of the pond to be maintained while providing relief to upstream areas from flood backwater. This is a highly automated system that would require ongoing operation and maintenance activities and a power source.

Alternative 1-7: Increase Size of Existing Floodplain Relief Culvert under NY-9G and Install Relief Culvert under Kelly Road

A review of topographic contours and known flooding information indicates that the existing culvert under NY-9G north of the intersection with Kelly Road may have been installed to allow stormwater drainage from west to east during small storms. However, during larger storms it appears that this culvert may permit a portion of flood flows to travel the opposite direction (from east to west), bypassing the Annandale Dam and inadvertently contributing to flooding at the Annandale Triangle. A second, partially blocked relief culvert is located approximately 450 feet south of the NY-9G Bridge, but appears to be a minor contributor to flows downstream and may also back up during very large flood flows.

Given the nature of the topography in this area, it appears that enlarging the size of the existing relief culvert north of Kelly Road and installing another culvert under Kelly Road would provide only minor benefits during small storm events but could significantly increase flooding at the Annandale Triangle during larger events. Instead, measures could be considered to retrofit the culvert such in order to maintain stormwater drainage but reduce flooding impacts at the Annandale Triangle.

Reach 1 – Recommendations

The primary recommendation for this reach is removal of Annandale Dam and replacement/upgrade of the NY-9G Bridge to provide a longer span (i.e., *Alternative 1-3*).

- Full dam removal would involve a significant up-front capital cost but would provide the greatest flood risk mitigation, ecological, and water quality benefits of the alternatives that were evaluated. Impounded sediments should be analyzed for possible additional contaminants, including those detected at the Lower Saw Kill dam, and options for sediment management would need to be assessed before the full cost and impact of dam removal can be understood. If the dam remains in place, the cost associated with the required repairs/upgrades could also be significant, which, when combined with ongoing operation and maintenance costs, could exceed the long-term cost of dam removal. Further refined hydraulic modeling of *Alternatives 1-4*, *1-5*, and *1-6*, which is beyond the scope of this study, is needed to allow a direct comparison of these alternatives to full dam removal with regards to their impacts on flood water surface elevations. However, it is unlikely that these alternatives would provide significant flood mitigation benefits, and none would provide comparable enhancements to stream connectivity without additional provisions for fish passage.

- Increasing the span of the NY-9G Bridge would contribute to flood risk reduction benefits at the bridge and in the Kelly Road neighborhood, which is a known area of flooding. The bridge is state-owned; stakeholders should consider contacting NYSDOT for more information regarding any plans regarding replacement or rehabilitation of the bridge and to share their concerns.

- While *Alternative 1-3* is expected to increase downstream flood water surface elevations in the vicinity of the River Road Bridge, the River Road Bridge is in need of flood risk mitigation measures already, as the bridge is currently undersized and overtops during the 50- and 100-year floods. The potential flood risk mitigation measures for the River Road Bridge and the downstream parking lot described in *Alternative 1-1* should be assessed.

Consideration should also be given to retrofitting the existing culvert under NY-9G north of the intersection with Kelly Road, by installing a one-way valve or similar mechanism, to limit diversion of flood flows toward the Annandale Triangle. This alternative would require more detailed hydraulic analysis of the culvert in support of design and permitting.

6.2.2 Reach #2: Aspinwall Road Bridges and Residential Neighborhood

Aspinwall Road crosses the Saw Kill in two locations, both of which are documented flooding locations. Both of these bridges sit lower in elevation relative to their approaches and form hydraulic constrictions in the stream channel due to their relatively narrow bridge openings and limited vertical clearance.

Alternative 2-1: Replace and Upgrade downstream Aspinwall Bridge

This alternative involves replacement of the downstream Aspinwall Road Bridge with a longer bridge span and at a higher elevation. The current span of the downstream Aspinwall Road Bridge is 26 feet. As indicated previously, NYSDEC recommends that new and replacement bridges be constructed with a span of 1.25 times the width of the stream channel bed. The HEC-RAS model was updated to reflect an increase in the span to 60 feet (which is anticipated to exceed the NYSDEC recommendation) based on visual interpretation of aerial imagery and LiDAR data available for this reach. In addition, the bridge deck was raised by 3 feet and the solid stone guardrails were eliminated in order to reduce the backwater effect caused by the bridge and reduce the risk of overtopping. The road was also raised to meet the elevated bridge deck. The degree to which the bridge deck and road surface could be elevated is limited by the elevation of the road approaches and the potential to cause adverse road drainage conditions.

The model indicates that these changes to the bridge would result in a decrease in flood elevations of up to 1 foot at the lower Aspinwall Road Bridge during the existing 10-year flood, with smaller decreases expected for most of the other floods analyzed. Smaller decreases in flood water surface elevations are expected for larger storm. Currently, the bridge is predicted to overtop during all flood events analyzed, which is consistent with the flooding that occurs along Aspinwall Road. These decreases in flood elevation caused by increasing the height and span of the bridge opening are not enough to prevent the bridge from overtopping, but by also raising the bridge, the frequency with which the bridge is overtopped may be reduced. Under the modeled scenario where the bridge deck is raised and the span increased, the bridge no longer overtops during the 10-year flood under existing or future climate conditions, and the risk is significantly reduced for the 50-year flood under both scenarios. Risk to the bridge would not be completely eliminated under this scenario, as the bridge would still be under "pressure flow" conditions under all flood scenarios analyzed.

The private properties upstream of downstream Aspinwall Road Bridge will also experience decreases in flood elevations of up to 1 foot at the downstream Aspinwall Road Bridge during the existing 10-year flood, with smaller decreases expected for most of the other floods analyzed and for areas farther upstream.

Flood elevations at the upstream Aspinwall Road Bridge are expected to decrease by smaller amounts (approximately 0.1-0.3 feet for most flood events). The upstream Aspinwall Bridge would continue to overtop in the existing and future 10-, 50-, and 100-year flood events. The exception is the future 100-year flood scenario, which is predicted to experience a flood level increase of approximately 0.2 feet. The limited flood risk mitigation benefits to the upper bridge may be due to the length of channel between the two bridges and the presence of wetland areas that may store floodwaters and help to dampen impacts between the two sites.

In addition to reducing flood impacts, increasing the span of the bridge would allow the bridge to encompass the streambanks and would provide some room for channel movement adjustment under the bridge, which would reduce geomorphic risk to the bridge and improve terrestrial and aquatic passage under the bridge. Raising the bridge and road approaches may negatively impact the private driveway at 102 Manor Road, which would have to be addressed in the bridge replacement design.

Alternative 2-2: Replace Both Aspinwall Road Bridges

The upstream Aspinwall Road Bridge consists of a 27-foot span with timber guardrails which sits slightly below the adjacent road approaches. The bridge is poorly aligned with the stream, crossing it at an angle that provides little room for channel movement and adjustments.

The modifications to the downstream Aspinwall Road Bridge described under *Alternative 2-1* were incorporated into *Alternative 2-2*. In addition, replacement of the upstream Aspinwall Road Bridge was considered. In order to determine whether replacement of the upstream bridge would have any measurable impact, the bridge was first removed entirely from the HEC-RAS model in which the downstream crossing had already been modified.

Model results indicate that replacing the upstream bridge would provide no additional reduction in flood water surface elevations compared to *Alternative 2-1*. The small size of the upstream bridge and its location in the very bottom of the floodplain, as well as the long extent of backwater impacts from the downstream bridge (depicted in flood profile plots provided in *Appendices D and E*) past the upstream bridge, limit the flood mitigation benefits of removing the upstream bridge for the floods assessed. Therefore, more detailed modeling of a modified upstream Aspinwall Road bridge was not performed.

Although replacing the upstream Aspinwall Road Bridge with a higher or longer bridge is expected to have minimal, if any, impact on flood water surface elevations, replacing the bridge with a higher bridge deck could decrease the frequency with which the bridge overtops by raising it above flood elevations. Simultaneously increasing the deck span or realigning the bridge to cross the stream perpendicular to the channel would reduce geomorphic risk by providing the channel more room to adjust to flood flows under the bridge.

Reach 2 – Recommendations

Replacement of the downstream Aspinwall Road Bridge with a longer bridge span and at a higher elevation is recommended to reduce flood risk at both Aspinwall Road Bridges and adjacent residential areas. Replacement of the upstream Aspinwall Bridge with a higher, longer, and realigned bridge may also reduce the frequency of overtopping and to reduce geomorphic risk during smaller storms, if the local topography allows such a replacement.

6.2.3 Reach #3: Mill Road Dam Impoundment and Downstream Area

The Mill Road Dam is a privately-owned concrete and masonry dam structure located approximately 650 feet downstream of the Mill Road Bridge over the Saw Kill. As with the Annandale Dam, the Mill Road Dam impounds water during floods, which increases flood risk to structures upstream of the dam, including the Mill Road Bridge and a section of Mill Road approximately 700 feet south of the bridge, which overtops during large floods. The flood inundation maps in *Appendix B* indicate that one or more structures may be inundated during a 100-year flood and driveways, docks, and other site elements may be impacted. During Tropical Storm Irene, floodwaters overtopped the dam abutments, circumventing the dam training walls, and caused severe erosion on private property adjacent to and downstream of the dam, as shown in *Figure 2*. However, by retaining water, the dam may also provide some flood mitigation benefit to areas downstream, including the Town of Red Hook well intake.

Figure 2. Photographs of erosion caused by the overtopping of the left abutment at the Mill Road dam during Tropical Storm Irene in 2011

Alternative 3-1: Remove Mill Road Dam

The HEC-RAS model was used to simulate the removal of the dam and a small volume of sediment from the impoundment behind the dam. Detailed structural measurements were not available for the dam, but the dam appears to be built on a waterfall, so the dam was modeled by removing the dam structure and reducing the lowest channel elevation to an elevation 6 feet below the current spillway elevation. If the dam were to be removed, final channel bed elevations would be determined as part of the engineering design.

Under this scenario, the model results predict a reduction in flood water surface elevations of 6.6 to 7.6 feet for the flood scenarios analyzed. These elevations are well below the dam abutments which overtopped during Tropical Storm Irene, significantly reducing the risk of erosion that occurred during Irene and other large floods. Modeled flood levels also decreased at the Mill Road Bridge by 3.9 to 5.1 feet, with larger reductions expected for smaller floods under the existing climate scenario. Although the Mill Road Bridge does not overtop during any of the floods modeled, the bridge opening is expected to be submerged under the 50- and 100-year floods for both existing and future climate change scenarios. The model results indicates that the bridge opening will no longer be submerged, reducing risk of damage to the Mill Road Bridge by high flows, debris, and geomorphic adjustment. Additionally, no increases in flood elevations are predicted at the Town of Red Hook well intake or at the Linden Avenue Bridge, located downstream of the dam.

Some of the factors that may be considered by the dam owner, if they are contemplating the removal of this dam could include:

- **Failure Risk:** All dams present some risk for catastrophic failure (i.e., the sudden breach or failure of the dam during a flood event, which causes a wave of water and debris to be released over a short period of time and flow downstream, possibly resulting in further risk to human safety and infrastructure downstream). The only way to completely eliminate the risk associated with a catastrophic failure is to remove the dam. The Mill Road Dam is currently rated a Hazard Class "B" (Intermediate Hazard) dam, meaning that it presents a risk to homes, infrastructure, and the environment, but loss of human life is not expected if the structure were to fail (NYSDEC, n.d.). According to the New York State Inventory of Dams (accessed 2/15/18), the dam's condition was not rated.

- **Current Use of the Impoundment:** Currently, the dam and its impoundment support a number of recreational uses and the pond is an important aesthetic and cultural feature for the property owners around the pond and local residents. The dam owner does not currently actively use or maintain the structure, but is considering potential alternative uses (see below). It is generally believed that property owners along the impoundment shoreline would prefer the impoundment to remain in place.

- **Potential Alternative Uses of the Structure:** The Mill Road dam may be under consideration for a hydroelectric installation. The impoundment could also potentially be retrofitted to provide a small amount of flood storage. The latter would require further assessment using a linked hydrologic and hydraulic model to determine the amount of potential flood storage.

- **Ecological and Water Quality Impacts of Removal:** By impounding water and sediment, the dam has caused the impounded area of stream to become more homogenous, thereby providing less valuable habitat to aquatic wildlife. Impounded bodies of water also tend to have elevated temperatures and have lower dissolved oxygen concentrations than would be expected if the reach were free-flowing, leading to water quality concerns in the impoundment and in areas downstream where the warmed water is eventually released. The shallower depths and warmer water in the impoundment, coupled with nutrient loadings from the watershed and accumulated sediments, contributes further to oxygen depletion and growth of aquatic plants and algae in the impoundment. Removal of the dam would restore a more natural flow regime, which would likely improve both stream habitat and water quality. The dam appears to have been constructed at the site of a natural waterfall; therefore any fish passage benefits achieved by dam removal would be limited to safer downstream passage and a reduction in the height of the climb for upstream-migrating juvenile eels

- **Management of Impounded Sediment:** The dam impounds an unknown quantity of sediment. The presence of contaminants in the sediment has not been assessed. Sediment sampling and testing would have to be conducted to estimate the quantity of sediment in the impoundment and to characterize the sediment for possible contaminants, which would inform the feasibility of dam removal and potential costs.

Alternative 3-2: Expand Riparian Buffer and Increase Flood Storage at Greig Farm

At Greig Farm, located approximately 3,000 feet upstream of the Mill Road Dam, the land adjoining the river is farmed right up to the narrow riparian buffer. There are some undercut banks and evidence of minor lateral erosion in this reach of the river. This alternative involves expanding the riparian buffer by planting up to 15 acres of land located within the mapped 500-year floodplain. The land is already protected from future development by a partial conservation easement. The proposed restoration concept would also increase flood storage by regrading and planting 8.8 acres of upland areas and/or the existing 100-year floodplain to create additional forested floodplain at a lower elevation. This 8.8 acre-area is relatively large compared to the approximately 27-acre Mill Road Dam impoundment, and therefore could provide a significant flood storage benefit, which may help reduce flood risk and observed flooding impacts in downstream areas associated with Mill Road Dam, as described in *Alternative 3-1*.

The riparian buffer restoration project would also provide ecological and water quality benefits by enhancing riparian habitat and reducing nonpoint source runoff from agricultural practices on the adjacent farmland. Although this land is already partially protected through a conservation easement, discussion with the landowner is recommended to better evaluate the feasibility of this alternative.

Alternative 3-3: Reactivate Stream Meanders Downstream of Mill Road Dam

As described in *Section 5*, the reach downstream of the Mill Road Dam has been artificially straightened and dredged, with no floodplain access and degraded aquatic habitat. A high-flow intake channel feeds a pond located adjacent to the Town of Red Hook well field. This alternative consists of reactivating the former meander channel immediately downstream of the dam (e.g., by excavating one or more areas between the current stream channel and the former channel), to serve as the primary channel during low to medium flows, to slow flood flows, to reconnect the floodplain, and to improve the quality of in-stream habitat. Filling of the existing connector channel and pond could also be considered to improve the quality of pumped groundwater. This alternative should be discussed with affected landowners to further evaluate feasibility.

Reach 3 – Recommendations

The riparian buffer and floodplain restoration concepts presented in *Alternatives 3-2* and *3-3* are recommended to reduce flood risk both upstream and downstream of Mill Road Dam, regardless of whether dam removal is considered. These restoration concepts also have applicability at other locations in the Saw Kill watershed, as discussed in the "targeted recommendations" section of this memorandum. Removal of Mill Road Dam would have significant flood risk mitigation benefits, but there may be opposition from the dam owner, waterfront property owners, and other members of the community who use the pond for recreation. Further discussion with affected landowners and other stakeholders is recommended to better gauge interest in removing the dam

6.2.4 Reach #4: US-9 Bridge and Upstream Reach

The US-9 Bridge, constructed in 1928, is a known hydraulic constriction, with the bridge opening under pressure flow during floods as small as the 10-year flood. The 2017 NYSDOT hydraulic summary for the bridge notes that "the bridge has a significant flood history" and that it has been placed on a Flood

Watch, and recommends that the bridge be replaced as it is "past useful lifespan". During the 2017 field visits Fuss & O'Neill noted spalled concrete on the bridge structure and concrete guardrails, sections of concrete hanging from the underside of the bridge, and other signs of deterioration or damage. Immediately upstream of the bridge, land is actively farmed right up to the river's edge, and farm equipment or structures may be located within the 100-year floodplain.

Alternative 4-1: Replace and Upgrade the US-9 Bridge

Replacement of the bridge was not directly modeled in HEC-RAS, as the replacement could take many forms. Instead, the impact of replacing the bridge was evaluated indirectly by removing the bridge from the model entirely to demonstrate the maximum potential flood mitigation benefits of a sufficiently large bridge opening. The resulting model predicts a maximum 1.8-foot decrease in flood elevations at the US-9 Bridge across all of the flood scenarios considered, and less than 0.1-foot decrease in flood elevations at the Echo Valley Road Bridge (located approximately 3,200 feet upstream of the US-9 bridge) for the same scenarios. Flood elevations at the farm located upstream of the US-9 Bridge are expected to decrease by up to 1.8 feet, depending on the flood scenario and distance from the bridge.

This results of this simplified modeling scenario illustrate the relatively limited flood risk reduction benefits associated with increasing the bridge span or deck height within the limits of existing topography. A review of aerial imagery and topographic mapping of the site suggests that the floodplain has been filled and narrowed to support US-9, which is a major factor in constricting flood flows.

US-9 is also a potential barrier to terrestrial wildlife passage, as the bridge is located near a High and Low Priority Integrity-Based Linkage as indicated in mapping in the report *Planning for Resilient, Connected Natural Areas and Habitats: A Conservation Framework* developed for the Town of Red Hook in 2014. An increased bridge span that encompasses both streambanks and/or flood relief culverts could provide opportunities for both aquatic and terrestrial wildlife to pass safely beneath the busy highway above.

Reach 4 – Recommendations

The US-9 Bridge should be replaced with a longer bridge span by removing fill from the floodplain, and/or installing floodplain relief culverts. The replacement design should include provisions for terrestrial wildlife passage. The bridge is state-owned; stakeholders should consider contacting NYSDOT for more information regarding any plans regarding replacement or rehabilitation of the bridge and to share their concerns.

6.2.5 Reach #5: Echo Valley Road Bridge and Upstream Area

The Echo Valley Road Bridge was built in 1924 and is listed by NYSDOT as functionally obsolete, which may be due to its potential to flood or due to the poor alignment and narrow width of the bridge, which requires vehicles to slow down to safely cross the bridge. The bridge overtops during all floods analyzed, and (per *Appendix E)* the owner of the property downstream of the bridge has stated that he has lost land from erosion downstream of the bridged due to reconstruction of the bridge "on a skew". Beaver activity upstream of the bridge is currently impounding flows.

Alternative 5-1: Replace and Realign the Echo Valley Road Bridge

Replacement of the bridge would provide the opportunity to increase the span of the Echo Valley Road Bridge to increase flow capacity and reduce the frequency with which the road floods. Realignment of the bridge would reduce the geomorphic risk to the bridge as the channel shifts, as well as the risk of erosion to the downstream property owner. Realignment and widening of the roadway over the bridge may improve traffic safety but may also have the unintended consequence of increasing traffic speeds along this section of Echo Valley Road.

Alternative 5-2: Reconstruct the Upstream Channel with Stable Bed and Banks

This alternative involves reconstructing the upstream channel banks using log jams, toe wood, or other bank protection structures using natural materials in order to slow or reverse erosion and realign the stream. Restoration of stable channel banks would reduce the risk of obstructions forming in the channel in the future. Obstructions upstream of the bridge that have resulted in channel adjustment, including beaver dams, could also be removed. This alternative would likely not reduce flood levels, but would help reduce the risk of flood-related damages, including failure of the bridge or washouts on adjacent properties.

Reach 5 – Recommendations

Replacement and realignment of the Echo Valley Road Bridge and restoration of the upstream stream channel are both recommended for this reach of the Saw Kill. Straightening the alignment of Echo Valley Road and widening the bridge may be opposed by local landowners and other residents along Echo Valley Road due to traffic safety concerns. Further discussion with the affected landowners and other stakeholders is recommended to better evaluate the feasibility of replacing the bridge.

6.2.6 Reach #6: Battenfeld Road

In the upper watershed, Battenfeld Road is a known flooding location, with undersized culverts and a relic dam located along the road. The concrete dam has failed but the pieces of the structure remain in the channel restricting flow, as shown in *Figure 3*. A small wetland exists upstream of the structure where the former impoundment filled in and was colonized by vegetation. Downstream, flow appears to be intermittent.

Alternative 6-1: Remove the failed concrete dam at Battenfeld Road

At this site, removal of the failed concrete dam would be an appropriate measure to help prevent flooding of the adjacent roadway during a large storm. Some minor regrading of the wetland area upstream of the dam may be necessary to minimize the risk of mobilizing sediment that may block downstream culverts, but potential wetland impacts may be a permitting concern.

Reach 6 – Recommendations

Removal of the relic dam at Battenfeld Road is recommended as a relatively low-cost option to reduce localized flooding during large storms.

Figure 3. Photograph of relic dam at Battenfeld Road

7 Recommendations

This section describes recommended actions to meet the flood mitigation goals of this study, as well as ecological and water quality enhancement goals. The recommendations include site-specific, targeted, and watershed-wide recommendations.

- **Site-specific Recommendations** include site-specific projects and/or actions intended to address issues within specific stream reaches, stream corridors, and upland areas rather than watershed-wide. However, site-specific recommendations can also result in cumulative, long-term benefits across larger portions of the watershed. In addition to the descriptions provided below, conceptual images of each recommendation are included in *Appendix F* to illustrate the recommended site-specific actions and their anticipated impacts.

- **Targeted Recommendations** include actions to address common types of problems that are identified at representative locations throughout the watershed, but where additional field assessments or evaluations are required to develop more detailed site-specific recommendations. Targeted recommendations can have both short and long-term benefits.

- **Watershed-wide Recommendations** are recommendations that can be implemented throughout the Saw Kill watershed. These basic measures can be implemented in most areas and communities within the watershed and are intended to increase community resiliency and to enhance habitat and water quality. The flooding and water quality/habitat benefits of these measures are primarily long-term and cumulative in nature resulting from strengthened land use policy, land conservation, runoff reduction, pollution prevention and source controls, and improved stormwater management.

7.1 Site-Specific Recommendations

The major site-specific recommendations are summarized below and shown graphically on the conceptual recommendations figures in *Appendix F*. *Appendix H* provides estimated cost ranges for each site-specific recommendation.

1. **Remove Annandale Dam:** Remove the dam and remove, stabilize, or otherwise manage sediment and streambanks in the former impoundment in coordination with *Recommendation #2*. Stabilization can be achieved through use of toe wood and other structures formed from natural materials. Address potential downstream increases in flood elevations by selectively excavating sediment and/or or restoring floodplain access upstream or downstream of the dam.

2. **Replace NY-9G Bridge:** Replace the bridge with a longer span to better accommodate flood flows and streambanks in coordination with *Recommendation #1*. Stabilize the stream banks upstream and downstream of the bridge as needed using natural materials and plantings. Address potential downstream increases in flood elevations by selectively excavating sediment and/or or restoring floodplain access upstream or downstream of the bridge, within the dam impoundment and/or farther downstream.

3. **Replace downstream Aspinwall Road Bridge and elevate road approaches:** Elevate the bridge deck and increase the bridge span. Elevate both road approaches to match the bridge deck and prevent flood flows from circumventing the elevated bridge and eroding adjacent private property. Also consider replacement of the upstream Aspinwall Road Bridge with a higher, longer, and realigned bridge to reduce the frequency of overtopping of the upstream Aspinwall Road Bridge and to reduce geomorphic risk.

4. **Consider removal or modification of Mill Road Dam:** Conduct a public meeting to confirm public support or lack thereof for dam removal or modification to reduce flood levels, using new information presented herein regarding flood risk mitigation benefits. Conduct a more detailed feasibility study if warranted by public support.

5. **Expand riparian buffer and increase flood storage at Greig Farm:** Increase the riparian area by planting up to 15 acres to cover the 500-year floodplain on the farm's land, which is already partially protected by a conservation easement. Increase flood storage by grading and planting 8.8 acres of upland areas and/or the existing 100-year floodplain to create additional forested floodplain at a lower elevation. Discussion with the landowner is recommended to better evaluate the feasibility of this alternative.

6. **Reactivate stream meanders downstream of Mill Road Dam:** Reactivate the former meandering channel immediately downstream of the dam, to serve as the primary channel during low to medium flows, to slow flood flows, to reconnect the floodplain, and to improve the quality of in-stream habitat. Consider filling the existing connector channel and pond to improve the quality of pumped groundwater. Discuss this option with affected landowners to better evaluate feasibility. Consider this recommendation in coordination with *Recommendation #5*.

7. **Replace the US-9 Bridge:** Replace the US-9 Bridge with a longer span, and remove fill from the floodplain that constricts the channel to provide flow relief and floodplain access. Include provisions to enhance terrestrial wildlife passage under the bridge.

8. **Replace and realign Echo Valley Road Bridge:** Replace and realign the bridge with a larger span in coordination with *Recommendation #9*. Further discussion with the affected landowners and other stakeholders is recommended to better evaluate the feasibility of replacing the bridge.

9. **Reconstruct the channel upstream of Echo Valley Road Bridge with stable bed and banks:** Reconstruct the upstream channel banks using log jams, toe wood, or other bank protection structures using natural materials in order to slow or reverse erosion and realign the stream. Remove obstructions upstream of the bridge that have resulted in channel adjustment, including beaver dams in coordination with *Recommendation #8*.

10. **Remove the failed dam at Battenfeld Road** – Demolish and remove remaining concrete at the failed dam. Perform minor grading to prevent sediment behind the dam from clogging downstream culvert(s).

7.2 Targeted Recommendations

The following targeted recommendations are provided for the Saw Kill watershed. Mapping identifying specific parcels or areas of the watershed for which these recommendations could apply are provided in *Appendix I*.

7.2.1 Culvert Upgrades and Replacements

Culvert upgrades and replacements can have the dual benefit of reducing flood risks to the structures and structure upstream, and enhancing riverine connectivity. In 2016, the Dutchess County Soil and Water Conservation District assessed culverts throughout the Saw Kill watershed as part of a larger effort by the Hudson River Estuary Program to identify and mitigate problematic road-stream crossings. In 2017, a follow-up prioritization study of culverts within the Town of Red Hook was undertaken on behalf of the Town of Red Hook (Crawford & Associates Engineering, P.C. 2017). Both efforts assessed culverts in the watershed with regards to passability and hydraulic capacity. Comparison of these assessments with the culverts noted in *Table 1* as known flooding locations may help further prioritize culvert replacement.

In general, culverts which are located between two dammed impoundments or between two culverts not recommended for removal should receive a lower priority unless these adjacent dams or culverts are also recommended for removal. Replacement of culverts that impound water may require additional permitting and may have an impact on landowners if the impoundments are valued for recreation, aesthetics, or other uses. Culvert replacement designs should take into account the channel bed with, openness ratio, and other design considerations, consistent with the NYSDEC stream crossing standards. The 2017 culvert prioritization study by Crawford & Associates Engineering identified the "top 10" highest priority culverts for replacement or upgrade within the Town of Red Hook, which are located at the roads or intersections listed below:

- DC-20 Intersection of **Kelly Road** and **Whalesback Road**
- DC-21 **Aspinwall Road** (between Chestnut Street and Dogwood Street)
- DC-36 and DC-37 **Norton Road** (near Stone Church Road)
- DC-38 **Norton Road** (nearby road not listed)
- DC-40 **Norton Road** (nearby road not listed)
- DC-42 **Fraleigh Lane** (between Rose Hill and Echo Valley Road)
- DC-46 **Fraleigh Lane** (nearby road not listed)
- DC-61 **West Willets Drive** (near NY-199)
- DC-66 **Crestwood Road** (no nearby road listed)
- DC-113 **Feller New Mark Road** (near Crestwood Road)

Other potential high priority culverts that should be considered for replacement/upgrade are listed in the table of *Culvert Upgrades and Replacements* in *Appendix I*.

7.2.2 Floodplain Restoration and Reconnection

Floodplains are the low, periodically-flooded lands adjacent to rivers, lakes, and waterbodies. Floodplains of rivers and streams absorb runoff and buffer upland areas from flood damage. As discussed previously, floodplains in portions of the Saw Kill watershed have been developed for agricultural, industrial, commercial, and residential uses, and this development has increased the risk of flood inundation and erosion hazards. Floodplain width in the watershed is variable and is limited in some places by terraces of glacial or alluvial materials. The channel and floodplain have a legacy of artificial modification including dredging, straightening, and clearance for agriculture. Floodplain development has also reduced the natural ability of the floodplain to store water, which can increase flooding in downstream areas.

Riverine floodplain and stream restoration can reduce flood and erosion risks, improve water quality and habitat for wildlife, and enhance recreational opportunities. Impacted floodplains and river corridors should be restored to an equilibrium condition by addressing the underlying causes of instability rather than the symptoms. For this reason, channelization and dredging of stream channels, construction of flood storage dams, or construction of streamside berms are not recommended as these actions may address a problem at one site but could negatively impact stream function and would likely cause negative impacts elsewhere along the river corridor.

Dredged and straightened reaches, a common feature in the Saw Kill watershed, tend to be slightly incised. **Reconnecting the channel to its floodplain** is the best way to restore incised reaches. This type of restoration consists of creating a floodplain "bench" or terrace adjacent to the stream channel, which creates additional volume to temporarily store floodwater and attenuate peak flows and sediment. Construction of broad floodplain benches is currently planned along the Wallkill main stem to reduce flood risk in that watershed. Bioengineering techniques can be used to stabilize the streambanks, thereby improving habitat value and providing some natural filtration and vegetative uptake of runoff that drains across these areas.

Another approach to restoring incised reaches involves the **addition of wood** to the channel such that sediment accumulation will raise the channel bed, allowing smaller floods to once again access the floodplain. The placement of engineered log jams in the river can also form new meanders by encouraging flows to "break out" of the channel and carve a new meander on the floodplain, as occurs naturally on straightened reaches elsewhere in the northeast. These techniques may also include acquiring at-risk structures for removal. A related approach is the use of **floodplain "relief culverts"** installed within a floodplain restriction to allow flows to spread across the entire floodplain, access side or "relief" channels, and reduce flow velocities in the main channel.

The limited geomorphic assessment of the Saw Kill watershed described in *Appendix E* focuses on sites along the lower reaches of the Saw Kill main stem, as these areas are the most developed in the watershed and therefore have the greatest risk and the greatest potential for restoration. Additional sites in the watershed where floodplain restoration/reconnection may provide flood risk mitigation and other benefits are identified in *Appendix I* and were selected based on the following criteria:

- Site is river adjacent,
- On undeveloped land cover type,
- In a location where Topography indicates disconnected floodplain
- In a location adjacent to or overlaps with habitat integrity areas identified in AKRF (2014).
- Preferred – location is publicly owned.

7.2.3 Riparian Restoration

Riparian buffers are naturally vegetated areas adjacent to streams, ponds, and wetlands. Healthy riparian buffers encourage filtration and infiltration of runoff and help slow and absorb high stream flows, which reduces both flood risk and drought and provides water quality and ecological benefits. The time required to realize the full habitat and fluvial benefits of riparian restoration is several decades from the initial planting, since trees need significant time to mature. Consequently, additional restoration actions, such as bank stabilization and other runoff reduction or floodplain restoration measures, are needed. Nonetheless, planting and enhancing riparian buffers should be considered a high priority in the Saw Kill watershed given the potential long-term advantages and the minimal effort, costs, and expertise required to achieve restoration.

Restoration of riparian buffers can be encouraged through cooperative programs with farmers, tax incentives, land conservation policy, and other measures, which are discussed further in *Section 7.2.4*, below. Mapping identifying other potential locations within the watershed that could be candidates for riparian buffer restoration is provided in *Appendix I*. Sites were identified based on the following criteria:

- Site is within 500-year floodplain or 500 feet of the river, and
- On developed or agricultural land cover type.
- Preferred – Adjacent to or overlaps with habitat integrity areas identified in AKRF (2014).

7.2.4 Land Conservation

One of the **most effective** ways for communities to become more resilient to flooding is by conserving land and discouraging development within floodplains and in upland areas. This is especially true of the Saw Kill watershed, given the high percentage (approximately 60%) of watershed land cover consisting of wetlands and forest. Conservation of these undeveloped land cover types allows precipitation to be absorbed or retained where it falls rather than becoming runoff, thereby reducing peak flows in streams. More than 2,800 acres of farmland and forest in and around the watershed are preserved through conservation easements, including approximately 28% of floodplain up to the 1 percent storm. However, a significant amount of land within the floodplain and in upland areas of the watershed is still subject to potential future development. Future development pressure in the watershed has the potential to further reduce the effectiveness of the existing forests and wetlands for mitigating flooding in the Saw Kill.

Vulnerable land in flood-prone areas can be protected through land use planning and regulations that prevent or discourage development within floodplains and river corridors, by purchasing land or acquiring conservation easements from willing sellers, coordinating buyouts of properties that are repeatedly flooded, and implementing a Transfer of Development Rights program. Further protection of the river corridor and upland areas through effective land use planning should be considered a high priority for the Saw Kill watershed, as well as continued land conservation and protection efforts of the Dutchess Land Conservancy, the Scenic Hudson, and the Winnakee Land Trust.

Protecting river corridors along straightened reaches should be considered a high priority, so flow and sediment attenuation can occur in an unconstrained manner. The river corridors to be protected for conservation planning purposes should encompass, as much as possible, the river corridor protection areas established by the Red Hook Community Preservation Plan and the Red Hook Open Space Plan, as well as any open space planning documents or policies adopted by other municipalities in the watershed. Other areas identified by the Town of Red Hook as priority conservation areas to ensure habitat connectivity (i.e., likely pathways for migration and movement among critical habitats per AKRF, 2014), and that also provide flood protection benefits, should be targeted for land conservation. Mapping showing potential candidate parcels is provided in *Appendix I*. These parcels were selected based on the following criteria:

- Site area is greater than 10 acres.
- Site located Within 500-year floodplain or 500 feet of the river.
- Parcel characterized undeveloped (forest or wetland) or largely undeveloped types of land cover.
- Parcel with no known conservation easement.
- Preferred – Adjacent to or overlaps with habitat integrity areas identified in AKRF (2014)

The map in *Appendix I* shows parcels that are already conserved as well as undeveloped parcels that could be targeted for conservation. Providing large contiguous tracts of conserved land can provide additional terrestrial connectivity and other ecological benefits.

In addition to the efforts of the land trusts in the watershed and the multiple funding sources listed in *Section* 8 that may support land conservation, land may be protected through designation as a Critical

Environmental Area (CEA) by any local agency. To be designated as a CEA, an area must have an exceptional or unique character with respect to one or more of the following:

- a benefit or threat to human health;
- a natural setting (e.g., fish and wildlife habitat, forest and vegetation, open space and areas of important aesthetic or scenic quality);
- agricultural, social, cultural, historic, archaeological, recreational, or educational values; or
- an inherent ecological, geological or hydrological sensitivity to change that may be adversely affected by any change.

Although CEA designation does not permanently protect land from development, following designation, any proposed development would trigger additional environmental reviews of projects as prescribed by 6 NYCRR Part 617 State Environmental Quality Review (SEQR) to ensure that they will not threaten the unique character of the land that resulted in the designation, including the potential to exacerbate flooding in the watershed and associated risks. More information regarding CEAs is available at http://www.dec.ny.gov/permits/6184.html.

7.3 Watershed-Wide Recommendations

7.3.1 Land Use Regulatory/Policy Changes

Municipal land use policies and regulations can help communities become more resilient to flooding by preserving undeveloped land, siting new development on locations less vulnerable to flooding, and promoting building and site designs that reduce runoff and are less likely to be damaged in a flood. Although a detailed review of the municipal land use regulations and policies of the watershed communities was beyond the scope of this study, the following general land use regulatory and policy recommendations should be considered further to increase community flood resiliency and provide other ecological benefits:

- **Consider adopting a No Adverse Impact (NAI) Floodplain Management policy.** NAI Floodplain Management is based on the principle that the actions of one property owner are not allowed to adversely affect the rights of other property owners in terms of increased flood peaks, increased flood stages, higher flood velocities, increased erosion and sedimentation, or other impacts.

- **Consider participation in the NFIP Community Rating System.** The National Flood Insurance Program Community Rating System (CRS) is a voluntary program that recognizes and encourages a community's efforts that exceed the NFIP minimum requirements for floodplain management. Many of the credits awarded by the CRS are specific to a community's floodplain programs and/or for protecting a community's natural floodplain functions, similar to the NAI Floodplain Management principles described above. In 2013, significant changes were made to the CRS credits that provide greater incentives to preserve and protect floodplains. By participating in the CRS program, communities can earn a discount for flood insurance premiums based upon the activities that reduce the risk of flooding within the community. The administrative cost of participating can be a burden for towns with few permanent staff, which is often the major impediment that keeps communities from participating in the program.

- **Review and amend municipal zoning and flood damage prevention ordinances to strengthen flood management standards beyond the minimum National Flood Insurance Program (NFIP) and state standards.** While the watershed communities have adopted the New York State flood damage prevention requirements regulating construction in floodplains, which is more stringent than federal NFIP standards in terms of freeboard and substantial improvement, other elements of the municipal zoning and flood damage prevention ordinances should be reviewed including amending nonconforming use provisions and requiring elevation of all building additions. Several of these requirements can increase a community's score under the Community Rating System (CRS) and increase the likelihood of reduced flood insurance premiums.

- **Consider implementing fluvial erosion hazard zoning to address riverine erosion hazards.** Such zoning, which is based on river corridors and flood hazard areas, can limit or prohibit development in fluvial erosion hazard areas, although it requires fluvial erosion hazard mapping. If the statutory basis for such zoning does not exist, an alternative to establishing formal overlay zoning would be to incorporate fluvial erosion hazards and river corridor protection concepts into local hazard mitigation plans and comprehensive plans.

- **Consider implementing a Transfer of Development Right (TDR) ordinance specifically to discourage development in floodplains.** A TDR ordinance allows the transfer of development rights of one parcel to another, thereby shifting density from areas designated for protection (such as floodplain and other sensitive natural areas) to areas more suitable for development. The program is designed to limit potential development in vulnerable areas, while compensating property owners for the reduction.

- **Review and amend existing conservation development, open space, or cluster development provisions in municipal subdivision ordinances.** Require the floodplain to be conserved, and require that new lots have adequate buildable areas above the natural 100-year flood elevation. Consider density bonus provisions, such as a maximum 10% increase in exchange for creation of contiguous (not fragmented) greenspace, the addition of trails, or an increase in riparian buffer widths. Permit density bonuses when coupled with restrictive covenants and easements. Require conservation and drainage easements in floodplain communities where lots may not be developed. Regulate development in areas with steep slopes, such that high slopes require greater setbacks than slopes with lower heights, to reduce the risk that structures will be undermined if the supporting slope is washed out during flood events.

- **Strengthen stormwater management requirements for development projects throughout the watershed and promote the use of Low Impact Development.** Review and amend zoning and subdivision ordinances to require all new development and re-development projects to comply with Low Impact Development (LID) standards and the New York State Stormwater Management Design Manual. Review and amend municipal street and parking lot design standards to reduce impervious cover and remove barriers to the use of LID. Update design storm precipitation amounts to promote more resilient stormwater drainage and BMP design. Stormwater and drainage-related infrastructure should be designed with storm intensities based on NOAA Atlas 14 (or NRCC atlas) to represent current precipitation conditions. For more resilient drainage design, consider additional increases to account for future changes in extreme rainfall under predicted climate change.

7.3.2 Stream Crossing Design Standards

Implementation of road-stream crossing design standards for new and replacement bridges and culverts can reduce flood risk by requiring that stream crossings be designed to allow natural flow and substrate conditions, which can both lower flood risk and improve aquatic habitat and connectivity. Stream crossing standards that promote stream continuity and flood resiliency have been adopted by New York State and other states in the northeast. In New York, these guidelines have been adopted as guidance, but town ordinances could be amended to require that these guidelines be used for new and replacement stream crossings. Adoption and implementation of local stream crossing guidelines can better position communities to receive post- disaster assistance from FEMA and a greater share of state funding from various programs, and FEMA post-disaster Public Assistance funding may be used to improve rather than simply replace stream crossings that sustain significant damage if the state or municipality has adopted, implemented, and consistently applied a set of guidelines prior to the disaster (Levine, August 2013).The watershed municipalities should also incorporate improved stream crossing guidelines into local design standards/policies for new permanent stream crossings (roads, driveways, paths, etc.) and replacement crossings.

While upgrading culverts to larger and more flood-resilient and stream-friendly designs can be more expensive in the short-term, long-term costs are significantly reduced as the road crossing survives larger storm events, therefore lasting longer, and generally requires less maintenance. When maintenance and replacement are considered, the average annual cost of an upgraded crossing can be lower over its lifetime than that of an undersized crossing over the same time (Industrial Economics, Incorporated, 2015; Levine, 2013; Gillespie, et al., 2014). Undersized and outdated stream crossings are even less cost-effective when climate change considerations – more frequent intense storms – are factored in.

7.3.3 Protection of Individual Properties

Several options exist for individual property owners to address flood risk on their property through floodproofing or elevating structures, filling portions of the property, or relocating outside of the floodplain.

Impacted property owners should be encouraged to purchase flood insurance through the National Flood Insurance Program (NFIP) and to make claims when the damage occurs. Having flood insurance can allow residents and business owners to recover more easily following a flood event, and submission of claims to the NFIP can provide evidence supporting requests by municipalities for funding for flood resiliency projects. Additional sources of information and funding for flood mitigation on individual properties is available from FEMA and the NFIP.

8 Potential Funding Sources

8.1 State Funding Sources

Tributary Restoration and Resiliency

The New York State Department of Environmental Conservation provides funding through the Hudson River Estuary Program to implement priorities outlined in the Hudson River Estuary Action Agenda aimed at conserving or improving clean water; fish, wildlife and their habitats; waterway access; the resiliency of communities; and river scenery. These opportunities are announced as Requests for Applications (RFAs) or as Requests for Proposals (RFPs). Approximately $1,025,000 is available in Hudson River Estuary Grants for Tributary Restoration and Resiliency. The minimum award amount is $10,500 and the maximum award is $1,025,000. To be eligible, projects must conserve and restore aquatic habitat connectivity for American eel and/or river herring found in the tributary streams of the Hudson River estuary watershed. Primary priority will be given to dam removal projects that are in close proximity to the Hudson, because of their importance for improving habitat for American eel and river herring. Projects must also be designed to pass, at a minimum, a 1% annual chance storm (100-year flood) to promote flood resiliency. Examples of projects which improve aquatic connectivity are: removal of dams; restoration of perched culverts to grade; replacement of culverts to reestablish natural stream-bottom conditions; right-sizing of bridges and culverts; and engineering and planning projects for removal of dams affecting eel or herring migration anywhere in the estuary watershed. Project proposals are due April 18, 2018 and the project timeline must show completion on or before September 30, 2021.

http://www.dec.ny.gov/lands/5091.html

BRIDGE NY Program

The New York State Department of Transportation (NYSDOT) is currently soliciting candidate projects for funding under the BRIDGE NY program. The BRIDGE NY program provides enhanced assistance for local governments to rehabilitate and replace bridges and culverts. Particular emphasis will be provided for projects that address poor structural conditions; mitigate weight restrictions or detours; facilitate economic development or increase competitiveness; **improve resiliency and/or reduce the risk of flooding.** Bridge projects must be on a public roadway that carries vehicular traffic; be eligible for federal aid; and shall follow the federal aid process. Culvert projects must be on a public highway and shall follow the State-aid process. The program will make available $21.7 million for bridges in the Hudson Valley, and $50 million for culverts statewide. Draft project proposals are due March 15, 2018 (culverts) and March 29, 2018 (bridges); final project proposals are due April 13, 2018 (culverts) and April 27, 2018 (bridges)

https://www.dot.ny.gov/bridgeny

Open Space Funding from the Environmental Protection Fund

Created in 1993, the New York State Environmental Protection Fund (EPF) provides mechanisms for open space conservation and land acquisition.

- Title 7 allocates funds to the Department of Environmental Conservation and the Office of Parks, Recreation and Historic Preservation for purchase of land to be included in the Forest Preserve, State Parks, the State Nature and Historical Preserve, State Historic Sites, Unique Areas and other categories.

- Title 9 provides funds for local governments and not-for-profit organizations to purchase park lands or historic resources as well to develop and preserve these resources.

New York's Open Space Conservation Plan serves as the blueprint for the State's land conservation efforts. The Open Space Plan identifies priority conservation in the projects based on analysis of open space conservation needs and public comments received during Regional Advisory Committee meetings and the Plan's review process, and priority projects are eligible for funding from the state's Environmental Protection Fund and other state, federal, and local funding sources. The Open Space Plan is required by law to be revised every three years. The Hudson Valley/New York City Foodshed is listed in the 2016 update to the plan as a Priority Project area and includes Dutchess County's important agricultural areas, as identified on the Agricultural Priority Areas map in the county's Agricultural and Farmland Protection Plan. These Agricultural Priority Areas in turn include large portions of the Saw Kill watershed within the towns of Red Hook, Milan, and Rhinebeck. Unconserved parcels in these areas may be eligible for conservation funding support from the EPF, particularly under Title 9.

http://www.dec.ny.gov/lands/317.html

Compensatory Wetland Mitigation

Construction projects in or near wetlands are required to avoid or reduce impacts to wetlands, but if impacts are unavoidable, NYSDEC requires development of plans to improve wetlands or wetland functions to compensate for wetland impacts resulting from the project. Typically, compensatory mitigation occurs on or near the associated construction project site, but when this is not possible, compensatory mitigation may be conducted by restoring off-site wetlands.

http://www.dec.ny.gov/permits/6273.html

Agricultural and Farmland Protection Program

The Agricultural and Farmland Protection Program was formed under Article 25-AAA of the Agriculture and Markets law in an effort to encourage further development of agriculture and farmland as part of the NYS Legislature's constitutional mandate to provide for the protection of agricultural lands. These programs, at the initial stage, help counties and municipalities plan for the future of agriculture in their communities. In later stages, it funds programs to implement those plans to keep agriculture strong and farmland in production.

- The Farmland Protection Planning Grants Program (FPPG), assists county and municipal (i.e., town, village, city) governments in developing agricultural and farmland protection plans which recommend policies and projects aimed at maintaining the economic viability of the State's agricultural industry and its supporting land base.

- The Farmland Implementation Grants Program (FPIG), assists counties, municipalities, soil and water conservation districts, and not-for-profit conservation organizations ("land trusts") in implementing farmland protection plans, including those created through FPPG.

- The Land Trust Grants Program awards state assistance to land trusts for activities that will assist counties and municipalities with their agricultural and farmland protection efforts.

https://www.agriculture.ny.gov/AP/agservices/farmprotect.html

Clean Water Act, Section 604(b) funding

The federal Clean Water Act provides funding to states for regional water quality management planning projects. Although water quality is the focus of this funding source, improved stormwater management can have flood resiliency benefits, by reducing runoff amounts from developed surfaces and therefore also reducing peak flows, as well as benefits to water quality and to habitat and ecosystem health. The Environmental Protection Agency (EPA) awards 604(b) grants to states, which in turn make awards to regional planning and interstate organizations. While EPA awards 604(b) funds annually, NYSDEC typically issues a Request for Applications (RFA) every 3-5 years and awards funds to multi-year projects. According to the NYSDEC website, "another RFA is not anticipated until 2018," indicating that funding may become available this year. The Hudson Valley Regional Council and NEIWPCC are among a selection of NYS Regional Planning Organizations and Interstate Organizations listed as eligible to apply for 604(b) funding.

http://www.dec.ny.gov/lands/53122.html

Clean Water State Revolving Fund

The Clean Water State Revolving Fund provides interest-free or low-interest rate financing for wastewater and water quality improvement projects to municipalities throughout New York State. A variety of point source, non-point source, and national estuary projects are eligible for financing, including stormwater management, habitat restoration and protection projects, and land acquisition for the purpose of protecting water quality. Assistance may only be provided for projects that are consistent with applicable area-wide water quality plans.

The Federal Environmental Protection Agency (EPA) annually provides a grant to the state to capitalize the CWSRF program. EFC uses this federal money, along with the required State match funds equal to 20% to fund projects for the purpose of preserving, protecting, or improving water quality. As borrowers repay their loans, repayments of principal and interest earnings are recycled back into the CWSRF program to finance new projects and allow the funds to "revolve" over time. There are several different types of financings available to CWSRF applicants. EFC provides both short and long-term financings, at zero or low interest to accommodate municipalities of all population sizes with varying financial needs. https://www.efc.ny.gov/cleanwater

Green Innovation Grant Program

The Green Innovation Grant Program (GIGP) supports projects that utilize unique stormwater infrastructure design and create cutting-edge green technologies. Examples of eligible practices include establishment or restoration of floodplains, riparian buffers; bioretention basins and rain gardens;

permeable pavement; green roofs and green walls; stormwater street trees/urban forestry programs; downspout disconnection; and stormwater harvesting and reuse. These projects are intended to leverage multiple benefits of green infrastructure. GIGP provides grants on a competitive basis to projects that improve water quality and demonstrate green stormwater infrastructure in New York. GIGP is administered by the New York State Environmental Facilities Corporation (EFC) and the grant provides funding of a minimum of 40% up to a maximum of 90% of the total eligible project costs as provided in the application. A minimum of 10% up to 60% match from state or local sources is required.

https://www.efc.ny.gov/GIGP

Water Quality Improvement Project (WQIP) Program

The Water Quality Improvement Project (WQIP) program funds projects that directly address water quality impairments or protect drinking water sources. Grant recipients may receive up to 75 percent of the project costs for non-agricultural nonpoint source abatement and control, land acquisition for source water protection, salt storage, aquatic habitat restoration, and municipal separate storm sewer system projects. Funded projects have included streambank stabilization/restoration, riparian buffer restoration, land acquisition for source water protection, and other nonpoint source projects. Aquatic habitat restoration projects may also include upgrade and replacement of road stream crossings, removal or breach of stream barriers (dams or weirs), or removal or alteration of impoundments. Projects that seek funding for planning or design only will be considered ineligible.

http://www.dec.ny.gov/pubs/4774.html

8.2 Federal Funding Sources

Eastern Brook Trout Joint Venture

The Eastern Brook Trout Joint Venture (EBTJV) funds projects that restore and conserve habitat necessary to support healthy and productive populations of wild brook trout. Federal funding is provided under the National Fish Habitat Action Plan through the U.S. Fish and Wildlife Service (USFWS). The maximum award amount for an individual project is $50,000. All proposed projects must be developed in coordination with the nearest USFWS Sponsoring Office. Funding can only be used for the on-the-ground habitat conservation and improvement projects and related design and monitoring activities.

http://easternbrooktrout.org/funding-opportunities/2017-ebtjv-fws-nfhp-project-funding-opportunity

HUD Community Development Block Grants

Title 1 of the Housing and Community Development Act of 1974 authorized the Community Development Block Grant program. The program is sponsored by the U.S. Department of Housing and Urban Development. The New York state program is administered through the New York State Office of Community Renewal.

CDBG-DR (disaster recovery) funds may be used to restore public facilities and infrastructure, rehabilitate or replace housing, acquire property, promote economic revitalization, and support hazard mitigation planning. CDBG-DR funds are intended to support long-term recovery from a specific natural disaster and may not be applied to recovery activities associated with other disasters. Projects must be tied to a Covered Storm, either by virtue of having been storm damaged, located within one of the Community Reconstruction Program areas, or located within one of the eligible counties (Dutchess County is one of these listed counties). The most recent funding round listed Covered Storms as Superstorm Sandy, Tropical Storm Lee, or Hurricane Irene.

http://www.nyshcr.org/Programs/NYS-CDBG/

Army Corps of Engineers Aquatic Ecosystem Restoration Program

Under Section 206 of the Water Resources Development Act of 1996 (33 U.S.C. 2330), the Army Corps of Engineers (USACE) can participate in the study, design and implementation of ecosystem restoration projects. Projects conducted in New York under this program have included freshwater wetland restoration, anadromous fish passage and dam removal, river restoration, and flood mitigation and ecosystem restoration reconnaissance studies. Projects must be in the public interest and cost effective and are limited to $10 million in Federal cost.

Non-Federal project sponsors must be public agencies or national non-profit organizations capable of undertaking future requirements for operation, maintenance, repair, replacement and rehabilitation (OMRR&R), or may be any non-profit organization if there are no future requirements for OMRR&R. The Corps of Engineers provides the first $100,000 of study costs. A non-Federal sponsor must contribute 50 percent of the cost of the feasibility study after the first $100,000 of expenditures, 35 percent of the cost of design and construction, and 100 percent of the cost of operation and maintenance.

The New York District of USACE does not provide a webpage detailing funding under Section 206, but the New England District provides a page with relevant information. http://www.nae.usace.army.mil/Missions/Public-Services/Continuing-Authorities-Program/Section-206/

USDA NRCS Funding Programs

The USDA Natural Resources Conservation Service (NRCS) works with land owners in New York to improve and protect soil, water, and other natural resources. NRCS has several funding programs in New York that help property owners address flooding and water quality issues.

- **The Emergency Watershed Protection (EWP) Program** is designed to help people and conserve natural resources by relieving imminent hazards to life and property caused by floods, fires, wind-storms, and other natural occurrences. EWP is an emergency recovery program, which responds to emergencies created by natural disasters; however, it is not necessary for a national emergency to be declared for an area to be eligible for assistance. EWP is designed for installation of recovery measures. Through the EWP program, the NRCS can help communities address watershed impairments that pose imminent threats to lives and property.

  Most EWP work in New York is for the protection of threatened infrastructure from continued stream erosion. Activities include providing financial and technical assistance to remove debris from stream channels, road culverts, and bridges, reshape and protect eroded banks, correct damaged drainage facilities, establish cover on critically eroding lands, remove wind-born debris, repair levees and structures, and repair conservation practices. All projects undertaken through EWP, with the exception of the purchase of floodplain easements, must have a project sponsor, such as a state, city, county, general improvement district, or conservation district. Federal EWP funding bears up to 75 percent of the construction costs. The remaining 25 percent must be obtained by the local sponsor.

Floodplain easements for restoring, protecting, maintaining, and enhancing the functions and values of floodplains, including associated wetlands and riparian areas, are available through EWP. These easements also help conserve fish and wildlife habitat, water quality, flood water retention, and ground water recharge, as well as safeguard lives and property from floods, drought, and erosion. EWP work is not limited to any one set of measures.

- **The Environmental Quality Incentives Program (EQIP)** provides financial and technical assistance to agricultural producers in order to address natural resource concerns and deliver environmental benefits such as improved water and air quality, conserved ground and surface water, reduced soil erosion and sedimentation or improved or created wildlife habitat. Agricultural producers and owners of non-industrial private forestland and Tribes are eligible to apply for EQIP. Eligible land includes cropland, rangeland, pastureland, non-industrial private forestland and other farm or ranch lands. Program priorities include reductions of non-point source pollution; helping producers with installing conservation practices such as Riparian Buffers, Cover Crops, Filter strips and Waterways to address phosphorus, pathogens, and sediment impairments that can relate to soil erosion, exposed soil, and the lack of riparian buffers or filter strips; and enhancing wildlife habitat

https://www.nrcs.usda.gov/wps/portal/nrcs/main/ny/programs/financial/

FEMA Hazard Mitigation Assistance Grant Programs

The Federal Emergency Management Agency's (FEMA) administers two major programs related to hazard mitigation: the National Flood Insurance Program and the Hazard Mitigation Assistance Program. FEMA's hazard mitigation assistance grant programs provide funding to protect life and property from future natural disasters. In New York, these programs are administered by the New York State Office of Emergency Management (NYS OEM), an office of New York's Division of Homeland Security and Emergency Services. FEMA flood hazard mitigation assistance funding is available to New York communities through the following programs:

- **Pre-Disaster Mitigation (PDM)** provides funds for hazard mitigation planning and the implementation of mitigation projects prior to a disaster. The goal of the PDM program is to reduce overall risk to the population and structures, while at the same time, also reducing reliance on Federal funding from actual disaster declarations. Funding is available on an annual basis (as available). The program provides funding with 75% federal share and 25% non-federal share (local government or other organization).

- **Flood Mitigation Assistance (FMA)** provides funds for projects to reduce or eliminate risk of flood damage to buildings that are insured under the National Flood Insurance Program (NFIP) on an annual basis. These are cost share grants for pre-disaster planning and projects, with a federal share (up to 100%) and non-federal share (local government or other organization).

- **Hazard Mitigation Grant Program (HMGP)** assists in implementing long-term hazard mitigation measures following Presidential disaster declarations. HMGP grants are post-disaster cost share grants consisting of 75% federal share and 25% non-federal share (local government or other organization). Funding is not currently available but may be made available after a disaster to implement plans or projects in accordance with State, Tribal, and local priorities.

- **Public Assistance (PA) Grants** provide assistance to local, tribal and state governments and certain types of Private Non-Profit (PNP) organizations so that communities can quickly respond to and recover from major disasters or emergencies declared by the President. Through the PA Program, supplemental Federal disaster grant assistance is provided for debris removal, emergency protective measures, and the repair, replacement, or restoration of disaster-damaged, publicly owned facilities and the facilities of certain PNP organizations. The PA Program also encourages protection of these damaged facilities from future events by providing assistance for hazard mitigation measures during the recovery process.

All local governments are required to have a FEMA-approved all-hazard mitigation plan in order to receive project funding from the Hazard Mitigation Grant Program (HMGP). The Pre-Disaster Mitigation Program (PDM) and the Flood Mitigation Assistance Program (FMA) require communities to have a FEMA-approved multi-hazard mitigation plan prior to requesting project implementation funds.

http://www.dhses.ny.gov/recovery/mitigation/planning.cfm#
http://www.dhses.ny.gov/grants/programs.cfm

8.3 Other Funding Sources

Town of Red Hook Community Preservation Fund

The Town of Red Hook has a local law imposing a two percent real estate transfer tax on the conveyance of interests in real property in the Town. Revenues derived from this tax are deposited in the Town of Red Hook Community Preservation Fund for the purpose of preserving open space, agricultural and historic places within the Town. This program has resulted in the preservation of significant agricultural open space in the Saw Kill watershed.

http://www.redhook.org/PDFs/CPA/cpalocallaw1of2007final.pdf

Stormwater Utilities

A stormwater utility operates much like a drinking water or sewer utility. Fees collected from property owners go into a dedicated fund to pay for the operation and maintenance of stormwater infrastructure, which can help mitigate peak flows as well as reduce the pollutant load carried by stormwater runoff. Stormwater utilities, which create a more equitable relationship between revenues collected and runoff generated from a site, are common in many parts of the U.S.

In the Saw Kill watershed, stormwater utilities could provide a dedicated source of funding for municipalities to construct and maintain green stormwater infrastructure, implement drainage system improvements (including culvert upgrades or replacements), and address MS4 permit compliance.

Healthy Watersheds Consortium Grant Program, U.S. Endowment for Forestry and Communities

The Healthy Watersheds Consortium is a partnership between the U.S. Endowment for Forestry and Communities, the U.S. Environmental Protection Agency, and the USDA Natural Resources Conservation Service, which provides funding for a healthy watershed program development project or local demonstration/training projects. Healthy watersheds protection is defined broadly as actions that preserve, enhance or improve aquatic ecosystems and supporting natural landscape and watershed processes such as hydrology in largely healthy watersheds. The grant is intended to support local protection and/or enhancement projects in healthy or primarily healthy watersheds that can be sustained into the future. Examples of projects include development of state, interstate, or tribal healthy watersheds strategies or plans that employ a systems-based, integrated approach to protection; environmental flows assessments; and public outreach and education on the importance of protecting healthy watersheds. For local demonstration/training projects, examples include protection of forested drinking water sources in headwaters, restoration of hydrologic connectivity, development of local conservation zoning and easement program plans. Funds received through this competition cannot be used for the purchase of land or conservation easements.

https://www.epa.gov/hwp/healthy-watersheds-consortium-grants-hwcg

Resilient Communities Program

In 2017, Wells Fargo and National Fish and Wildlife Foundation launched the Resilient Communities Program, designed to prepare for future environmental challenges by enhancing community capacity to plan and implement resiliency projects and improve the protections afforded by natural ecosystems by investing in green infrastructure and other measures. The program will focus on water quality and quantity declines, forest health concerns, and sea level rise. The program will emphasize community inclusion and assistance to traditionally underserved populations in vulnerable areas. In the northeast, eligible project types include restoration of wetlands and other ecosystems to help communities address floods and storm events, and aquatic organism passage. The program awarded approximately $2 million in grants to projects in 2017 and will award approximately $1.5 million in grants in 2018. Each grant will range from $200,000 to $500,000 depending on category and will be awarded to eligible entities working to help communities become more resilient. This program has one round of applications per year and awards approximately 3 to 6 grants annually. Additionally, approximately $500,000 is available in 2018 to support highly-impactful and visible projects that help communities understand, organize and take action to address risks and opportunities through improved resilience brought about by enhanced natural features. Pre-proposals for the 2018 Request for Proposals were due February 15, 2018, but funding may be pursued in 2019.

http://www.nfwf.org/resilientcommunities/Pages/home.aspx

8.4 Recommended Funding Strategy

Implementation of the flood mitigation recommendations identified in this report will require significant funding from grants and other sources, as well as collaboration between the watershed communities, county and state government, and landowners. *Table 10* identifies recommended sources of funding for each of the site-specific project recommendations.

A relative priority is assigned to each recommendation. **"Immediate priority"** recommendations are projects that are well-matched to a particular funding source with a fast-approaching application deadline (noted in the table) and/or face the fewest barriers to implementation based on available information. **"High priority"** recommendations are projects that would provide significant flood mitigation and other benefits, but which don't have an immediate funding application deadline or may require additional coordination with county and state government agencies. **"Medium priority"** recommendations are projects for which landowner support is uncertain (e.g., removal of Annandale Dam) or significantly longer lead times are anticipated.

Table 10. Funding Strategy for Flood Mitigation Project Recommendations

Recommendation[1]	Priority	Notes	Potential Funding Source	Funding Notes	Due Date
1. Remove Annandale Dam	Medium	• Remove dam • Remove, stabilize, or otherwise manage sediment and streambanks in the former impoundment • Address potential downstream increases in flood elevations by selectively excavating sediment and/or or restoring floodplain access upstream or downstream of the dam.	NYSDEC/HREP Tributary Restoration and Resiliency (future rounds) Water Quality Improvement Program (WQIP) Army Corps of Engineers Aquatic Ecosystem Restoration Program Resilient Communities Program	Award amounts and match requirements vary; consider multiple/ combined funding sources.	Various
2. Replace NY-9G Bridge	Medium	• Replace bridge with a longer span • Stabilize upstream and downstream streambanks as needed • Address potential downstream increases in flood elevations by selectively excavating sediment and/or or restoring floodplain access upstream or downstream of the bridge.	NYSDOT (state and federal sources)	State-owned bridge. Contact NYSDOT to determine plans for bridge and voice concerns.	N.A.

3. Replace downstream Aspinwall Road bridge and elevate road approaches	**Immediate**	• Design, permitting, and construction of replacement bridge. Anticipated project tasks include:
		  ○ Design/engineering
		  ○ Permitting
		  ○ Right of way
		  ○ Construction
		  ○ Construction Inspection.
		• Final design for replacement of Aspinwall Road bridge may differ from Recommendation #3 based on results of analyses performed during preliminary design and engineering.
			BRIDGE NY Initiative
			https://www.dot.ny.gov/bridgeny
				Amount available: $21,700,000 for bridges in the Hudson Valley
				Minimum Award Amount: $250,000 (per individual bridge)
				Maximum Award Amount: $5,000,000 (per individual bridge)
				Match Requirement: 5%
					Draft Application Submittals March 29, 2018
					
					Final Application Submittals April 27, 2018

Combined feasibility study for the following recommendations:
 	
4. Consider removal or modification of Mill Road Dam
 	
5. Reactivate Meanders downstream of Mill Road Dam
 	
6. Expand riparian buffer and increase flood storage at Greig Farm
	Immediate	• Conduct feasibility study regarding dam removal or other alternatives to modify Mill Road Dam, which may include the following analyses:
		  ○ Detailed hydraulic analysis
		  ○ Sediment characterization
		  ○ Ground survey
		  ○ Geotechnical investigation
		  ○ Investigation of potential impacts to wells
		  ○ Bathymetric survey of Mill Road Dam impoundment.
		• Conduct stakeholder outreach to discuss alternative flood risk reduction measures; determine feasibility based on input from landowners.
			NYSDEC/HREP Tributary Restoration and Resiliency
			http://www.dec.ny.gov/lands/5091.html
				Amount available: Approximately $1,025,000
				Minimum Award Amount: $10,500
				Maximum Award Amount: $1,025,000
				Match Requirement: 5%
					April 18, 2018

Table 10. Funding Strategy for Flood Mitigation Project Recommendations

Recommendation[1]	Priority	Notes	Potential Funding Source	Funding Notes	Due Date
		• Recommendations for Mill Road Dam and upstream/downstream areas are combined into a single feasibility study to maximize project benefits and increase chances of grant funding. • Pursue additional funding sources for implementation of approved project elements following completion of feasibility study.			
7. Replace US-9 Bridge	High	• Replace aging bridge with a larger span. • Remove fill from the floodplain to provide flow relief and floodplain access. • Include provisions to enhance terrestrial wildlife passage under the bridge.	NYSDOT (state and federal sources)	State-owned bridge. Contact NYSDOT to determine plans for bridge and voice concerns.	N.A.
8. Replace and realign Echo Valley Road bridge	Medium	• Replace and realign the bridge with a longer span	BRIDGE NY NRCS EWP FEMA programs Resilient Communities Program	Award amounts and match requirements vary; consider multiple/ combined funding sources	Various
9. Reconstruct channel upstream of Echo Valley Road bridge with stable bed and banks	Medium	• Design and implement bank protection structures using natural material in order to slow or reverse erosion and realign the stream. • Remove obstructions upstream of the bridge that have resulted in channel adjustment, including beaver dams.	NRCS EQIP or NRCS EWP https://www.nrcs.usda.gov/wps/portal/nrcs/main/ny/programs/financial/	**EQIP Maximum Award Amount:** $450,000 **EWP Match Requirement:** 25%	Applications are accepted on a continuous basis
10. Remove failed dam at Battenfeld Road	High	• Demolish and remove remaining concrete at failed dam. • Perform minor grading to remove and stabilize sediment behind dam.	Student Conservation Association Hudson Valley AmeriCorps Program (volunteer service project) https://www.thesca.org/serve/program/hudson-valley-corps	Contact Megan Lung, NYSDEC HREP, for more information	N.A.
Riparian Restoration	High	• Plant and enhance riparian buffers in areas where buffers have been impacted or eliminated	NYS Clean Water State Revolving Fund Green Innovation Grant Program (GIGP) Water Quality Improvement Program (WQIP) Army Corps of Engineers Aquatic Ecosystem Restoration Program NRCS EQIP and NRCS EWP Resilient Communities Program Trees for Tribs	Award amounts and match requirements vary; consider multiple/ combined funding sources	Various

Table 10. Funding Strategy for Flood Mitigation Project Recommendations

Recommendation[1]	Priority	Notes	Potential Funding Source	Funding Notes	Due Date
Replace undersized culverts on tributary streams	**Immediate**	• Replace and upgrade prioritized culverts on tributaries to the Saw Kill to increase flood resiliency.	BRIDGE NY Initiative https://www.dot.ny.gov/bridgeny **Amount available:** $50,000,000 for culverts statewide **Minimum Award Amount:**	$50,000 (per individual culvert) **Maximum Award Amount:** $1,000,000 (per individual culvert) **No Match Requirement** **Draft Application Submittals**	March 15, 2018 **Final Application Submittals** April 13, 2018
			NYSDEC/HREP Tributary Restoration and Resiliency http://www.dec.ny.gov/lands/5091.html	**Amount available:** Approximately $1,025,000 **Minimum Award Amount:** $10,500 **Maximum Award Amount:** $1,025,000 **Match Requirement:** 5%	April 18, 2018
			Water Quality Improvement Program (WQIP) Army Corps of Engineers Aquatic Ecosystem Restoration Program NRCS EQIP FEMA programs Resilient Communities Program Eastern Brook Trout Joint Venture	Award amounts and match requirements vary; consider multiple/ combined funding sources	Various
Floodplain Reconnection	Medium	• Create a floodplain "bench" or terrace adjacent to the stream channel to provide access to floodplain during high flows and to provide additional flood storage	NYS Clean Water State Revolving Fund Green Innovation Grant Program Water Quality Improvement Program (WQIP) Army Corps of Engineers Aquatic Ecosystem Restoration Program NRCS EQIP and NRCS EWP Resilient Communities Program Compensatory Wetland Mitigation Eastern Brook Trout Joint Venture	Award amounts and match requirements vary; consider multiple/ combined funding sources	Various
Land Conservation	High	• Acquire or place protections on parcels with undeveloped or agricultural land use types • Focus on large parcels, parcels adjacent to parcels with existing conservation easements, and parcels with wetland or unique habitat types and high value for connectivity	Agricultural and Farmland Protection Program Water Quality Improvement Program (WQIP) Open Space Funding from the Environmental Protection Fund Eastern Brook Trout Joint Venture	Award amounts and match requirements vary; consider multiple/ combined funding sources	Various

[1]As of March 2, 2018. Priority may change based on changes in site conditions, property ownership, availability of grants and proposal due dates, among other factors.

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Appendix A

Watershed Maps

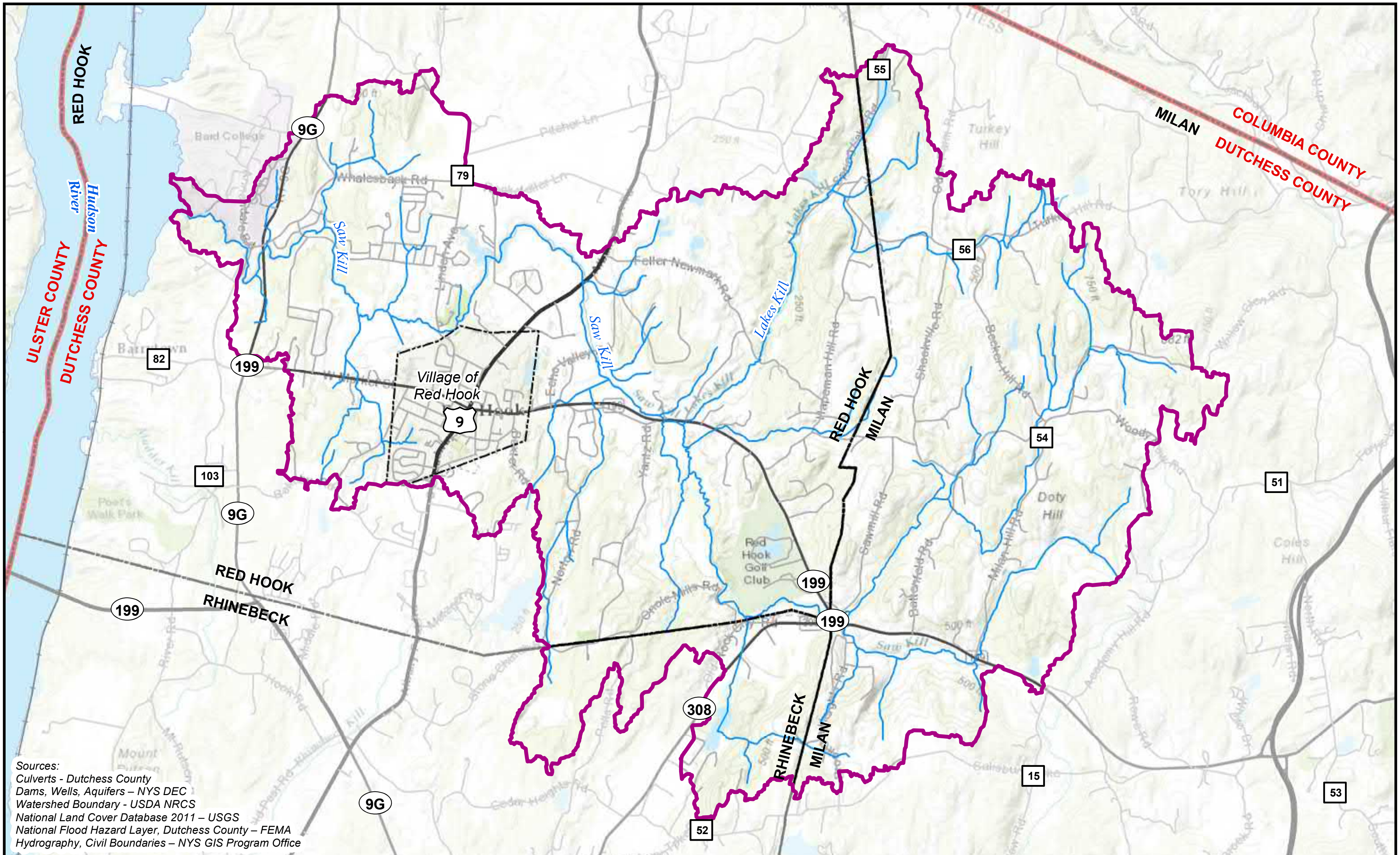

Figure 1: Watershed Overview

Saw Kill Watershed

FUSS & O'NEILL

PROJ. No. 20161136.A1N

DATE: AUGUST 2017

N W E S

0 0.5 1 1.5

Miles

Streams / Rivers

Watershed Boundary

Railroads

Villages

Towns

Counties

Path: K:\P2016\1136\A10\MXD\Watershed-wide Maps\Sawkill_WatershedResourceMap_20170822.mxd

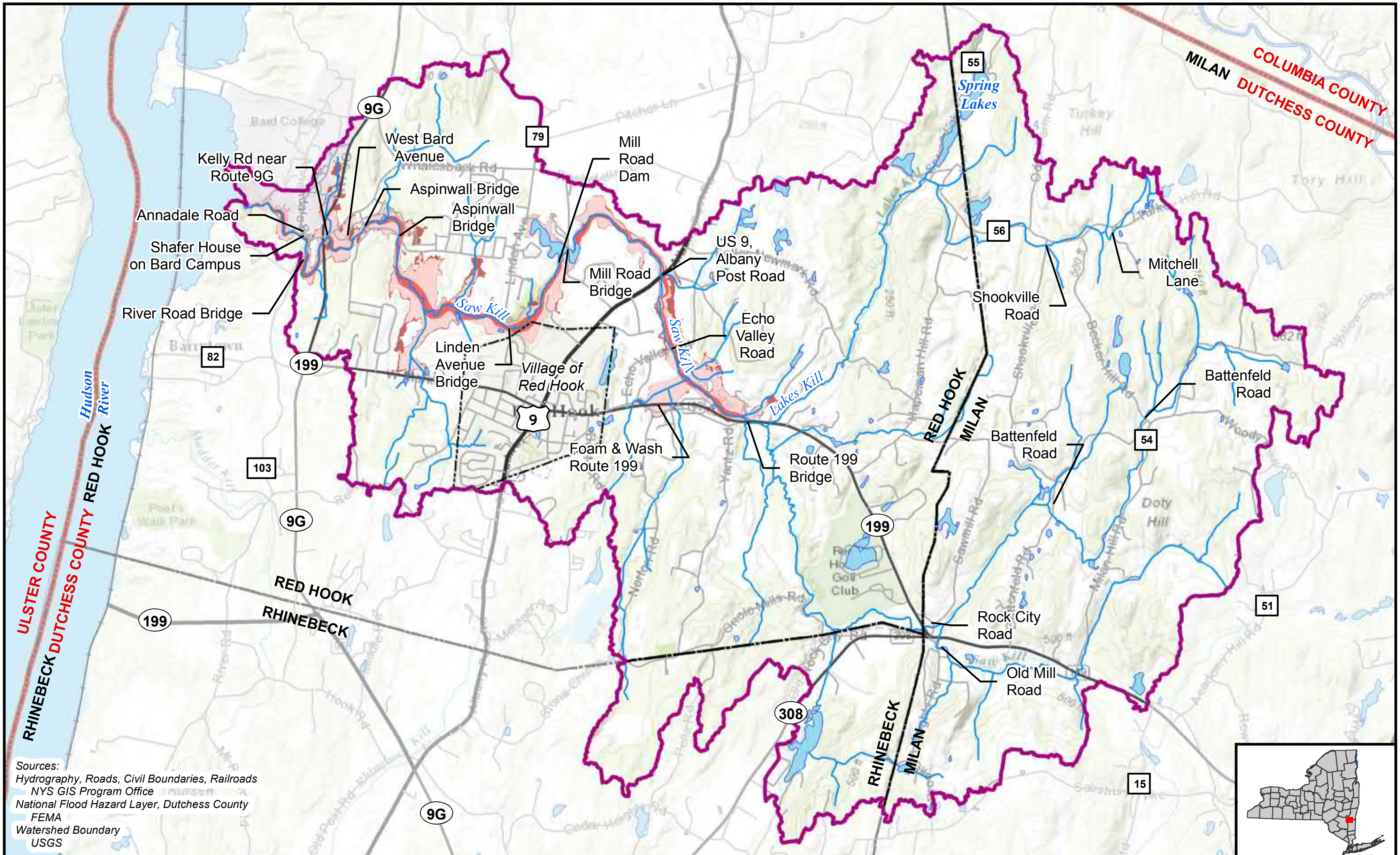

Figure 2: Areas Susceptible to Flooding and Flood Hazard Zones

Saw Kill Watershed

FUSS & O'NEILL

PROJ. No. 20161136.A1N

DATE: AUGUST 2017

0 0.5 1
Miles

FEMA Flood Zone

- 100-yr Flood Zone
- Regulatory Floodway
- 500-yr Flood Zone

- Streams / Rivers
- Surface Water
- Watershed Boundary
- Areas of Reported Flooding

Path: K:\P2016\1136\A10\MXD\Watershed-wide Maps\Sawkill_Watershed_FEMA_Zones_20170831.mxd

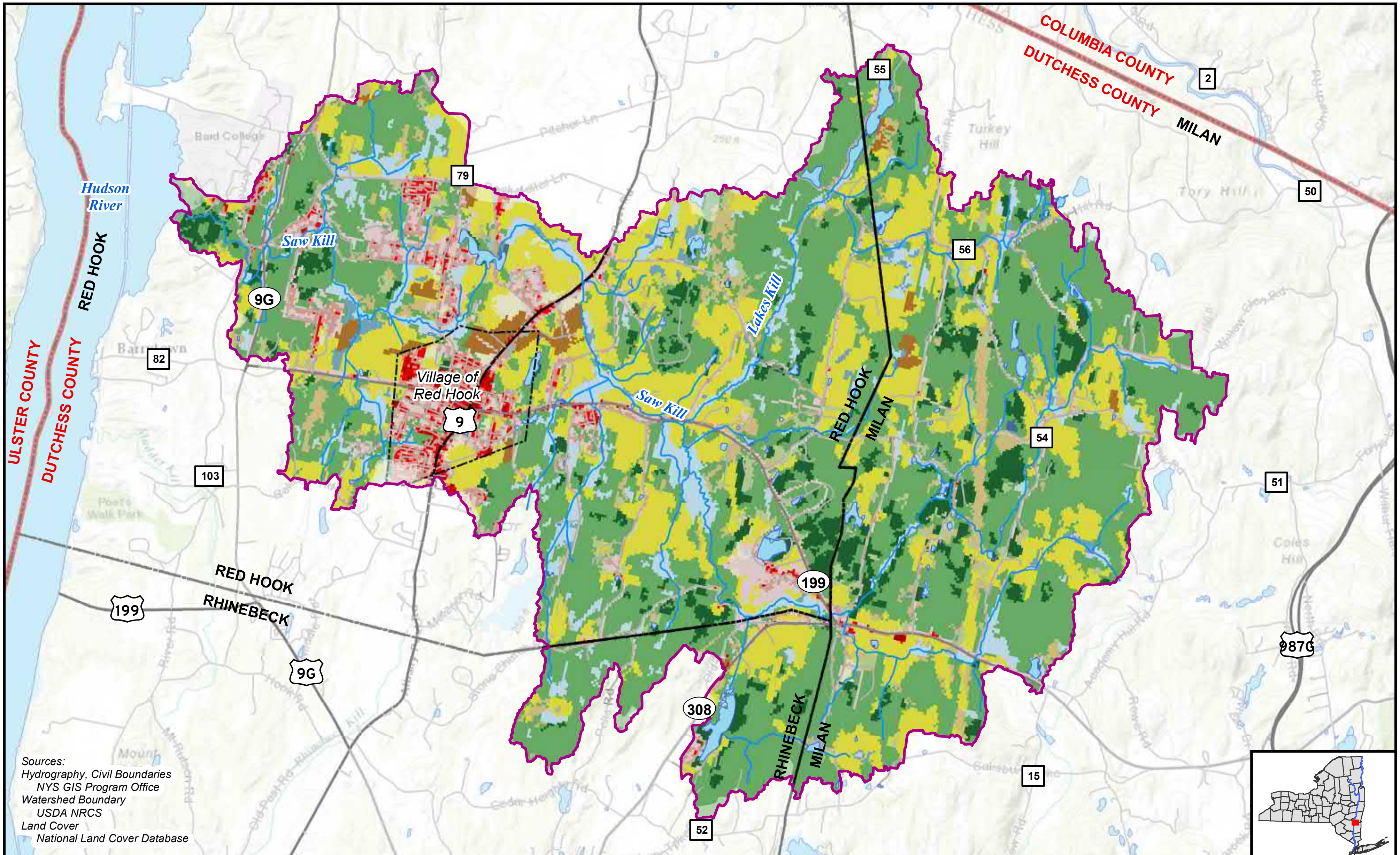

Figure 3: Watershed Land Cover

Saw Kill Watershed

FUSS & O'NEILL

PROJ. No. 20161136.A1N

DATE: AUGUST 2017

N E S W

0 0.5 1 1.5 Miles

- Watershed Boundary
- Surface Water
- Streams
- Counties
- Towns
- Villages
- Open Water
- Developed, Open Space
- Developed, Low Intensity
- Developed, Medium Intensity
- Developed, High Intensity
- Barren
- Deciduous Forest
- Coniferous Forest
- Mixed Forest
- Shrub/Scrub
- Herbaceous
- Hay/Pasture
- Cultivated Crops
- Woody Wetlands
- Emergent Herbaceous Wetlands

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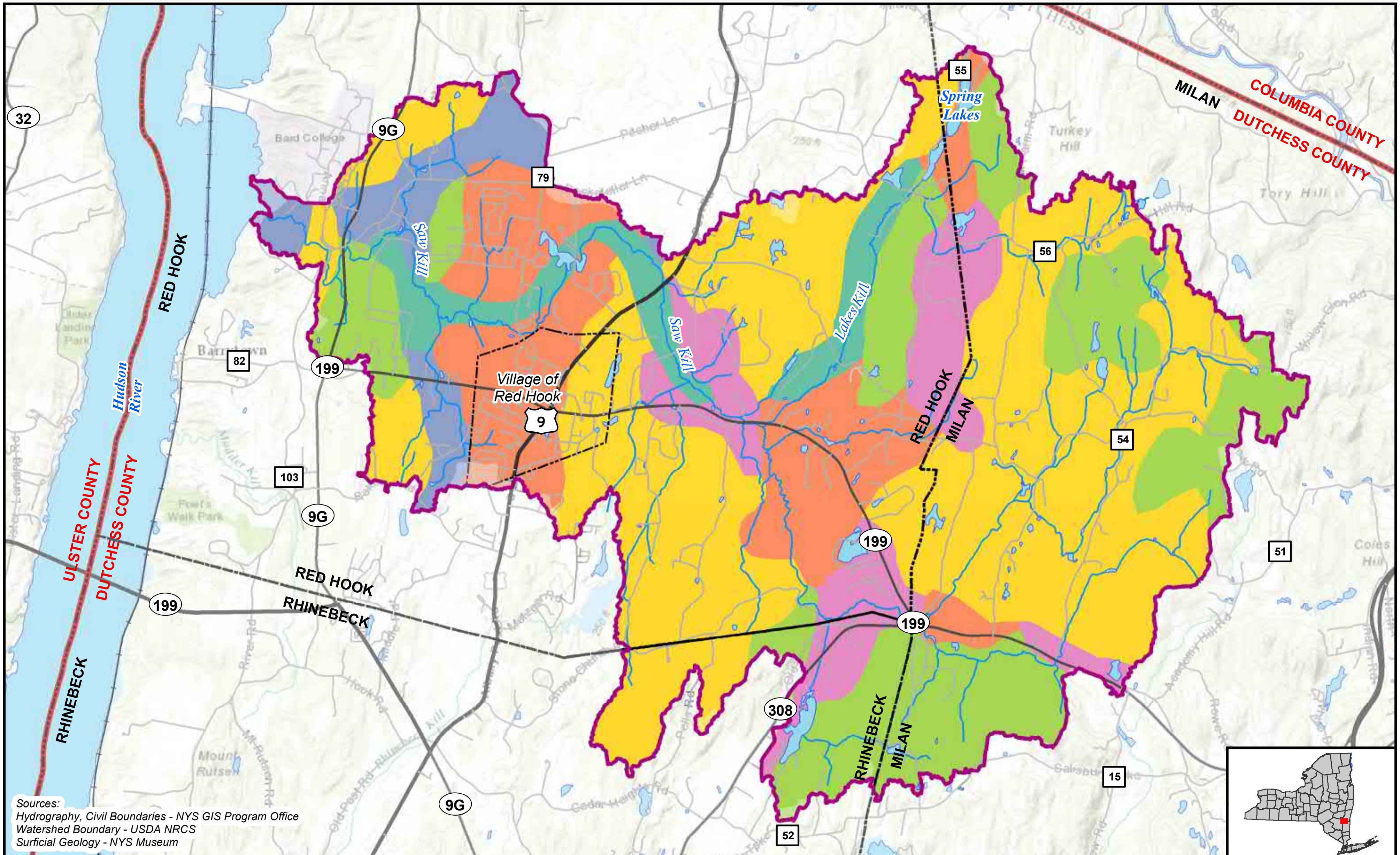

Figure 4: Surficial Geology

Saw Kill Watershed

FUSS & O'NEILL

PROJ. No. 20161136.A1N

DATE: AUGUST 2017

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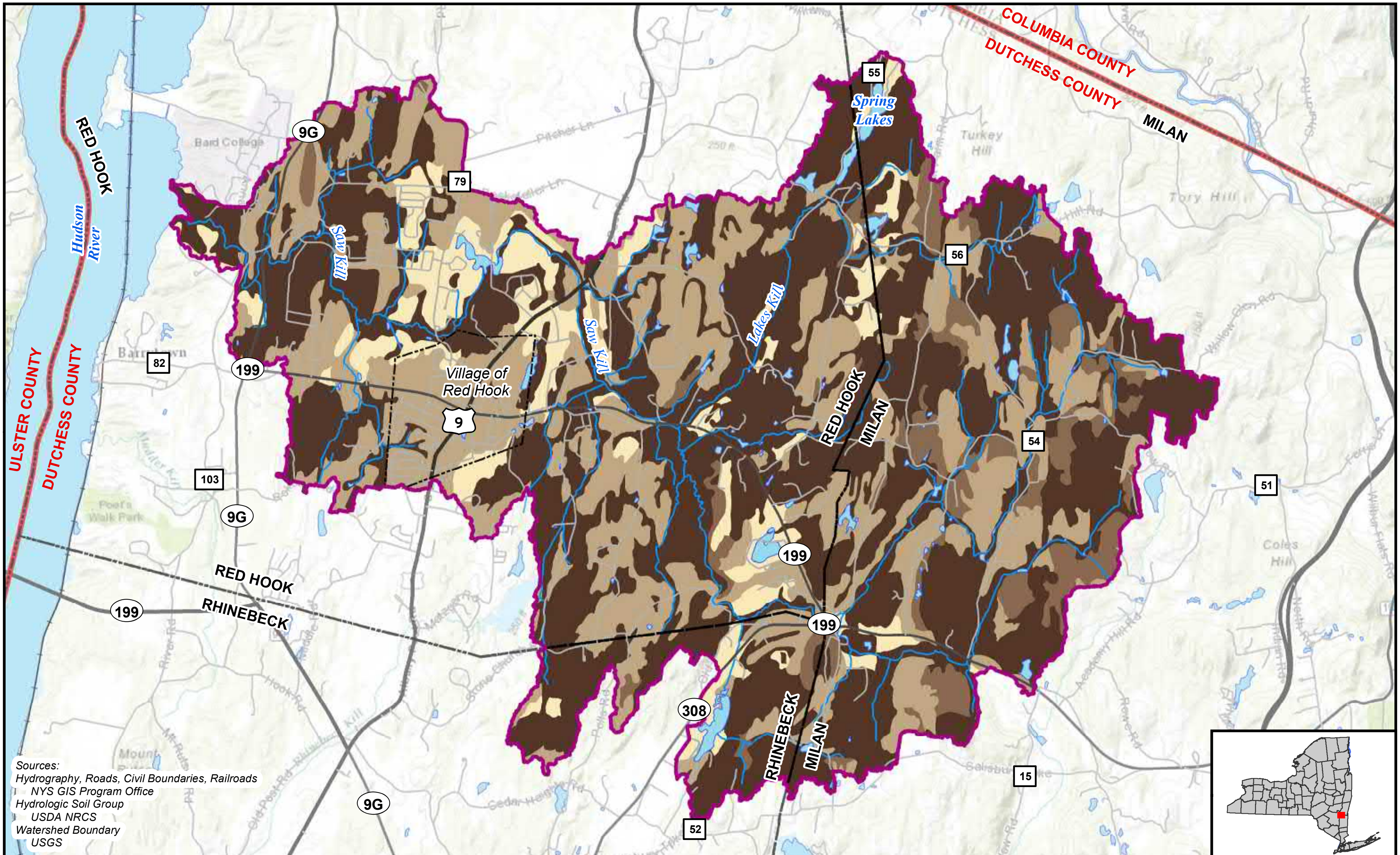

Figure 5: Hydrologic Soil Groups

Saw Kill Watershed

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PROJ. No. 20161136.A1N

DATE: AUGUST 2017

0 0.5 1 1.5
Miles

Hydrologic Soil Group

- A
- B
- C
- D

- Watershed Boundary
- Villages
- Towns
- Counties
- Surface Water
- Streams

Path: K:\P2016\1136\A10\MXD\Watershed-wide Maps\Sawkill_HydroSoils.mxd

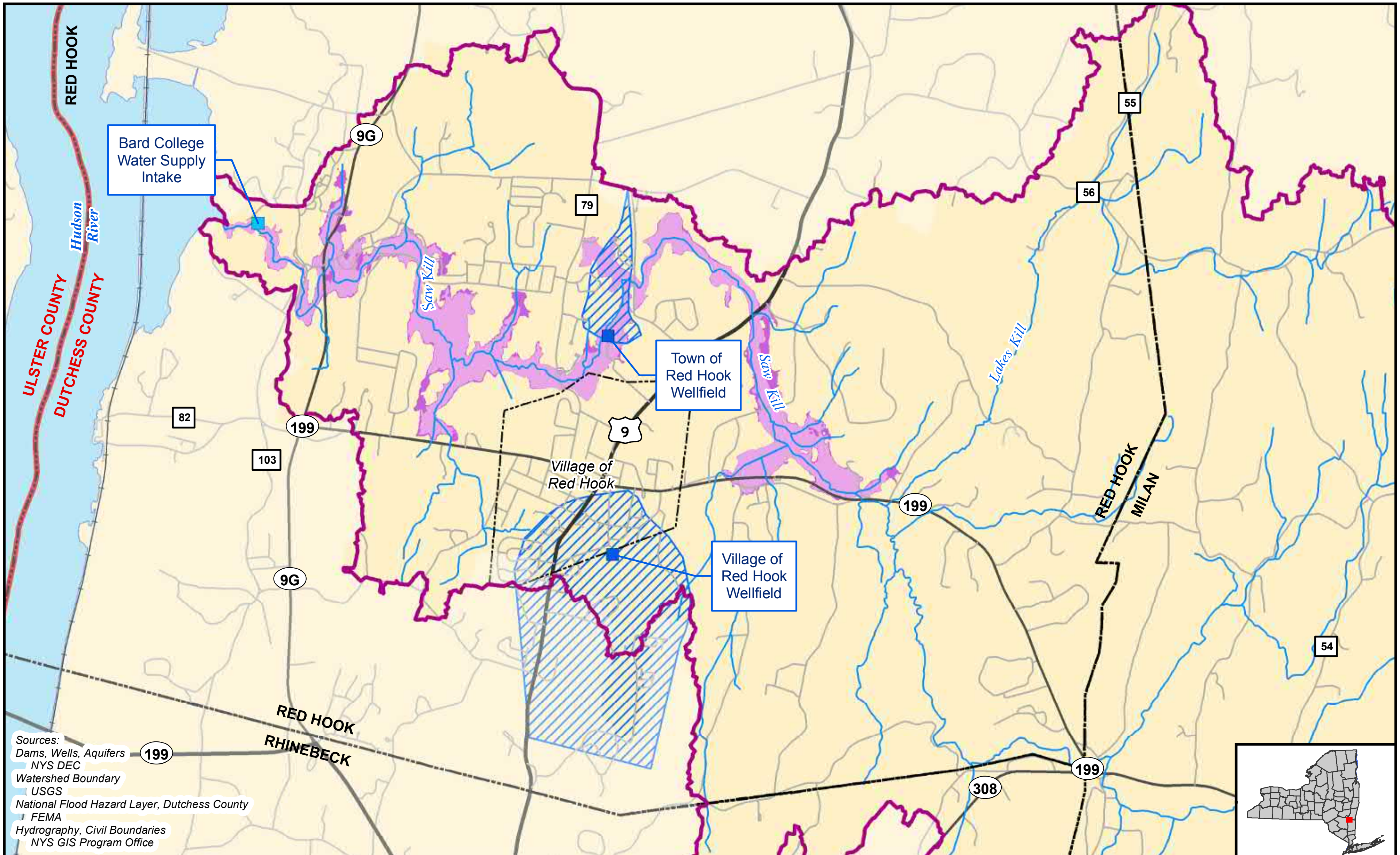

Figure 6: Water Resources

Saw Kill Watershed

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DATE: AUGUST 2017

N E S W

0 0.5 1 Miles

Water Supplies (approx. locations)

- Water Intake
- Wellfield
- Streams / Rivers
- Well Field Recharge Areas

FEMA Flood Zone

- 100-yr Flood Zone
- 500-yr Flood Zone
- Watershed Boundary

Path: K:\P2016\1136\A10\MXD\Watershed-wide Maps\Sawkill_WaterResources.mxd

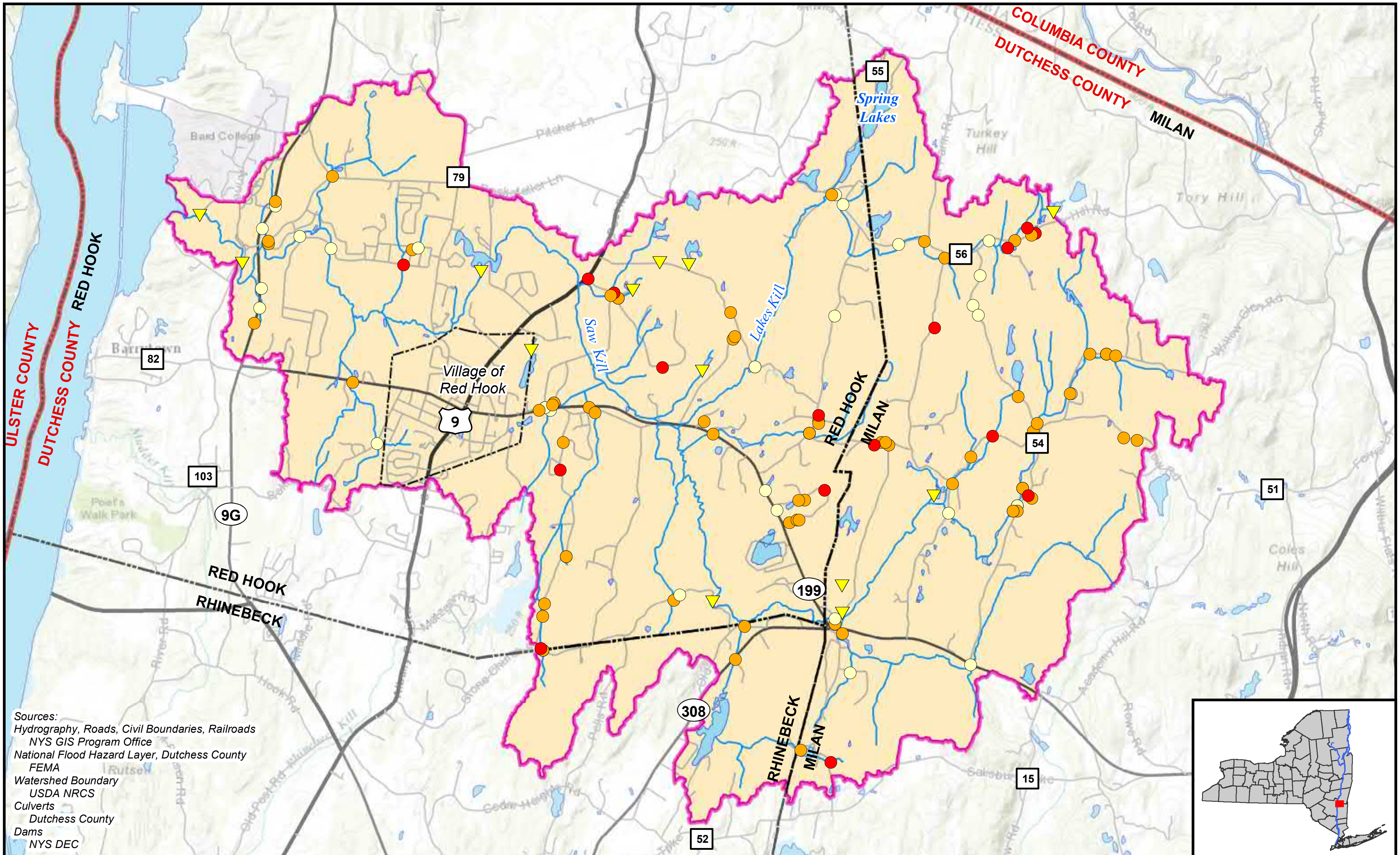

Figure 7: Aquatic Organism Passability

Saw Kill Watershed

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PROJ. No. 20161136.A1N

DATE: AUGUST 2017

0 0.5 1 1.5

Miles

Culvert Passability

- Minor barrier
- Moderate barrier
- Significant barrier
- Dams
- Surface Water
- Streams
- Watershed Boundary
- Watershed Boundary

Path: K:\P2016\1136\A10\MXD\Watershed-wide Maps\Sawkill_Passability.mxd

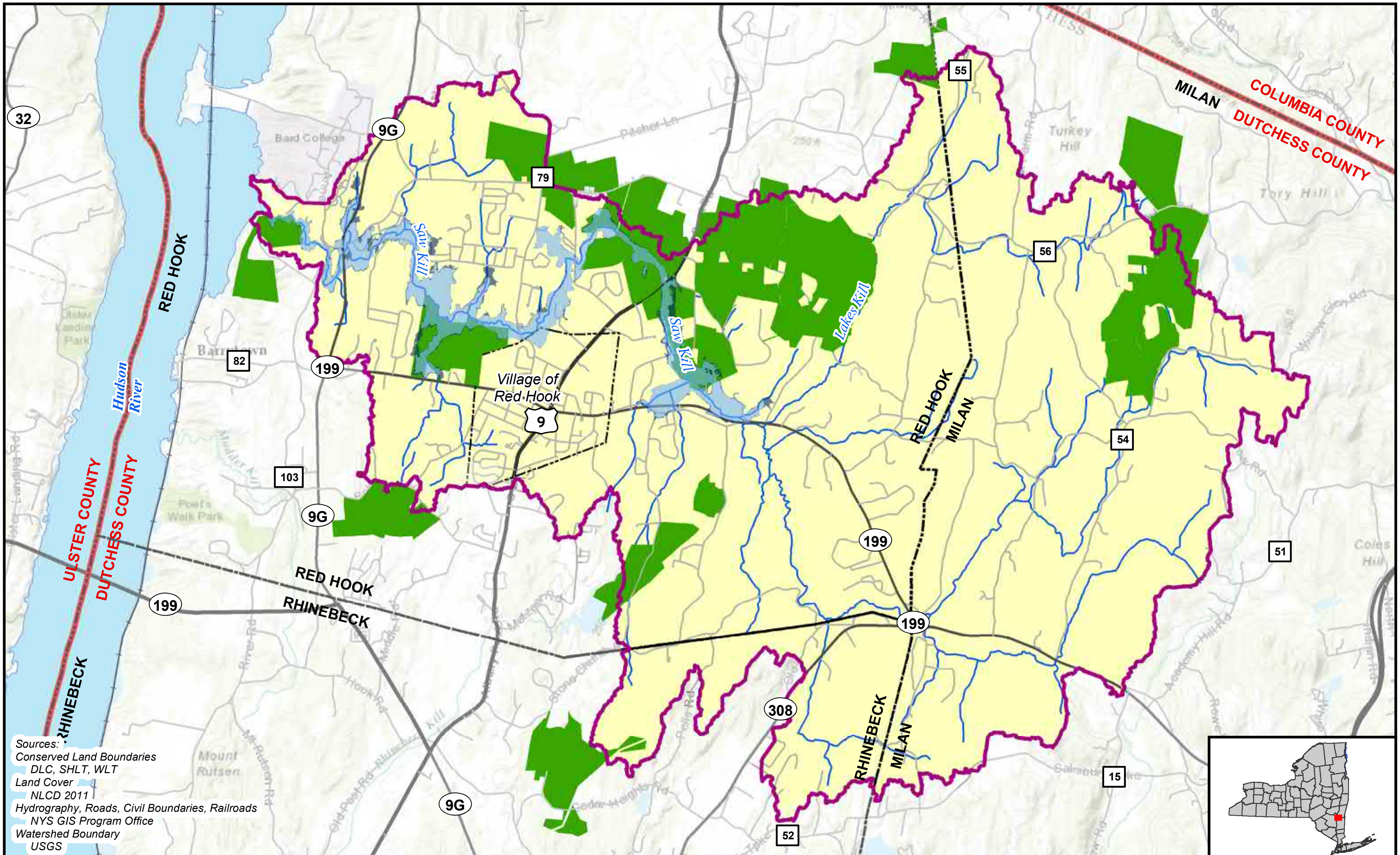


Figure 8: Conserved Lands

Saw Kill Watershed

Conserved Land

Non-conserved Lands

Watershed Boundary

100-yr Flood Zone

500-yr Flood Zone

Streams

FUSS & O'NEILL

PROJ. No. 20161136.A1N

DATE: AUGUST 2017

Path: K:\P2016\1136\A10\MXD\Watershed-wide Maps\Sawkill_ConservedLands.mxd

Appendix B

1% Annual Chance Flood Inundation Maps

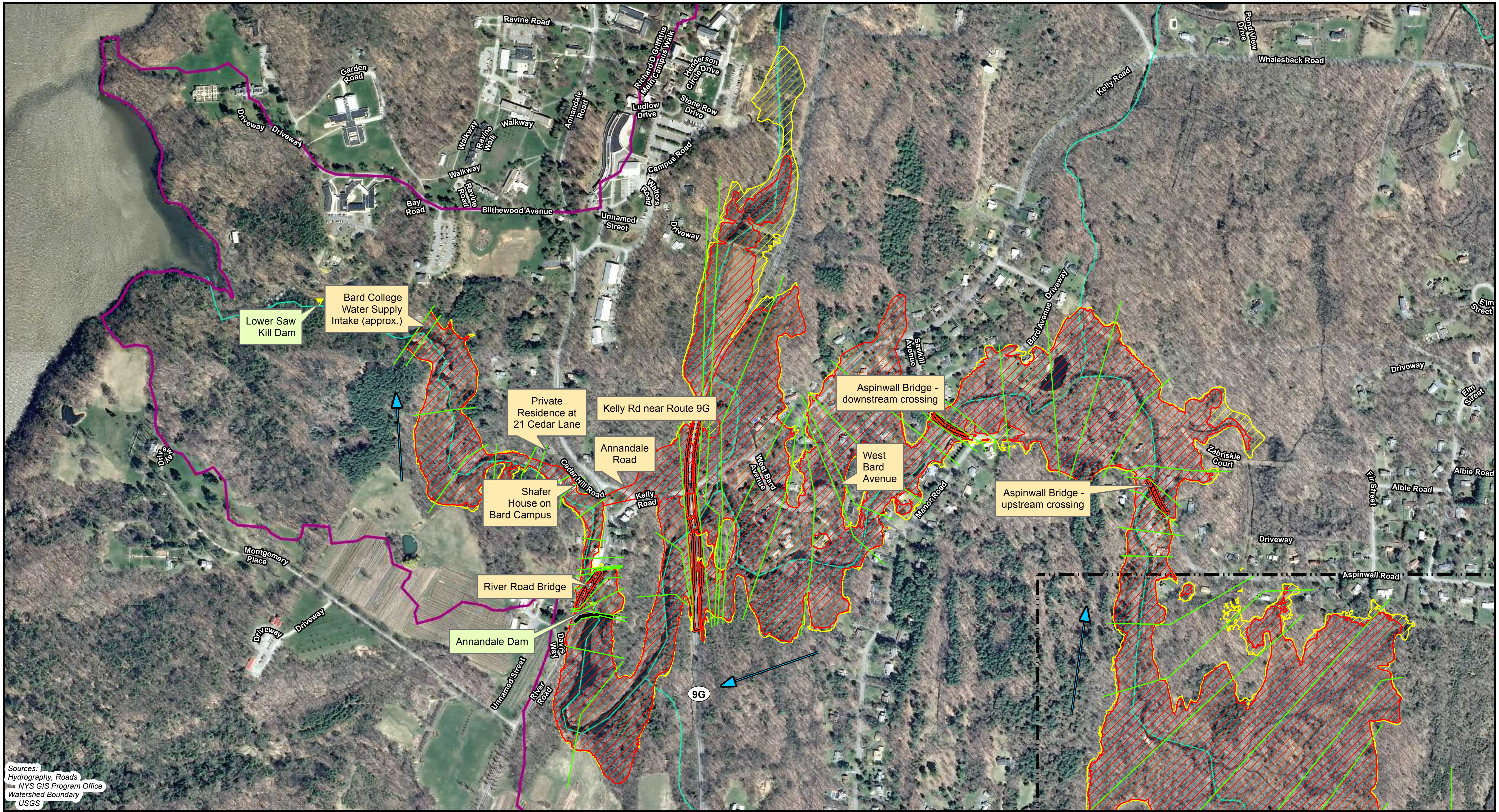


Figure 1-1: Inundation Map

Saw Kill Watershed

FUSS & O'NEILL

PROJ. No. 20161136.A1N

DATE: MARCH 2018

0 500 1,000 1,500

Feet

Existing Conditions 1% Annual Chance (100-Year) Flood Inundation Area (approx.)

Future Conditions 1% Annual Chance (100-Year) Flood Inundation Area (approx.)

Direction of Flow

Representative Cross Sections

Dam Crest

Roadway Crossings

Streams

Well Recharge Areas

Watershed Boundary

Match Line

Dams

Flooding Locations

Path: K:\P2016\1136\A1N\MXD\SawKill_ExistingConditions_InundationMap.mxd

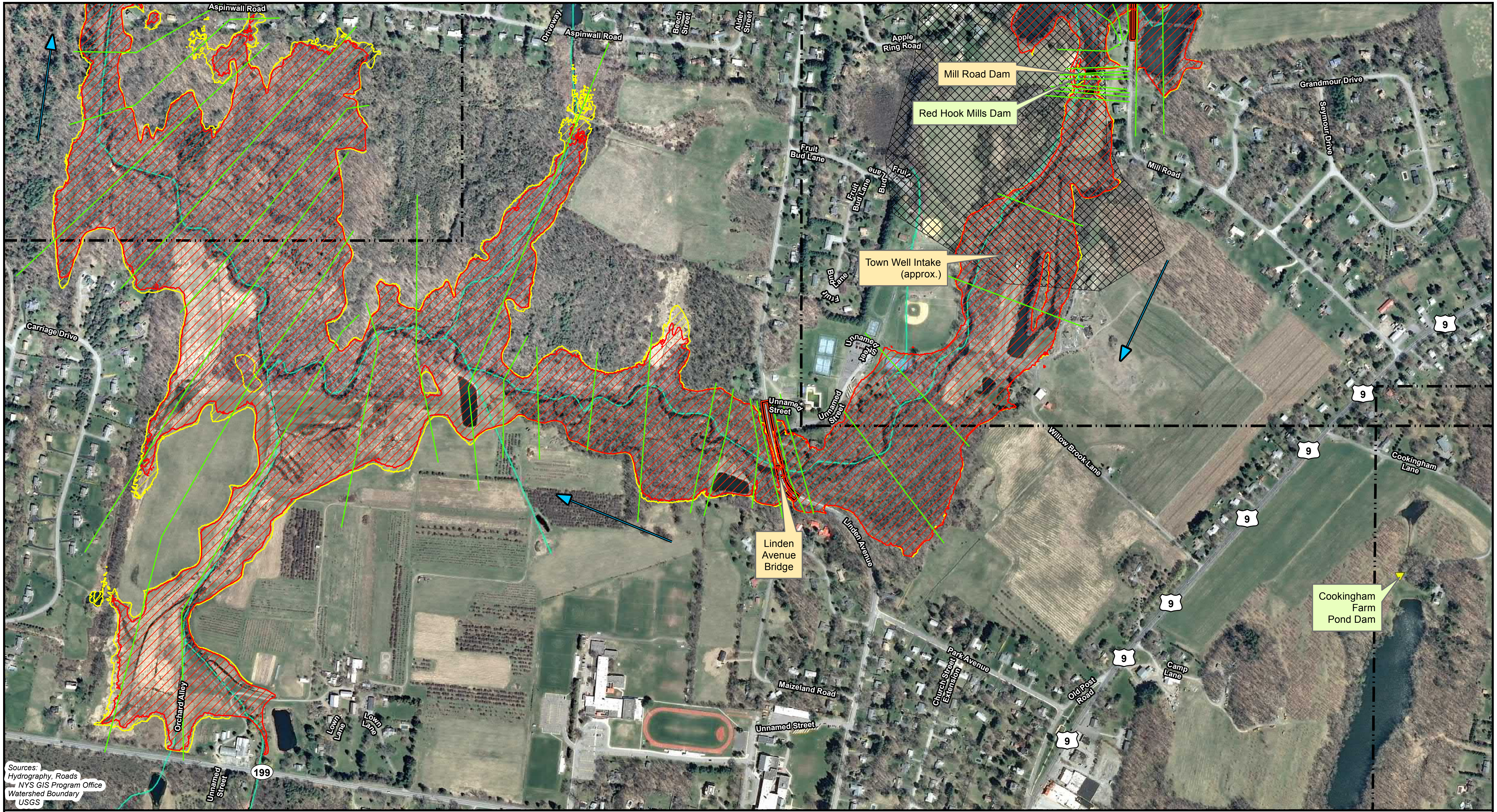


Figure 1-2: Inundation Map

Saw Kill Watershed

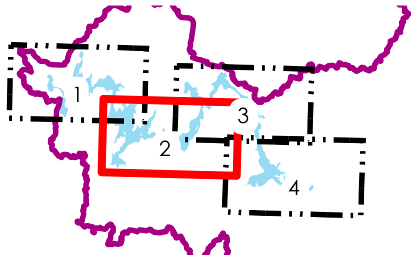
FUSS & O'NEILL

PROJ. No. 20161136.A1N

DATE: MARCH 2018

0 500 1,000 1,500

Feet



Existing Conditions 1% Annual Chance (100-Year) Flood Inundation Area (approx.)

Future Conditions 1% Annual Chance (100-Year) Flood Inundation Area (approx.)

Direction of Flow

Representative Cross Sections

Dam Crest

Roadway Crossings

Streams

Well Recharge Areas

Watershed Boundary

Match Line

Dams

Flooding Locations

Path: K:\P2016\1136\A1N\MXD\SawKill_ExistingConditions_InundationMap.mxd

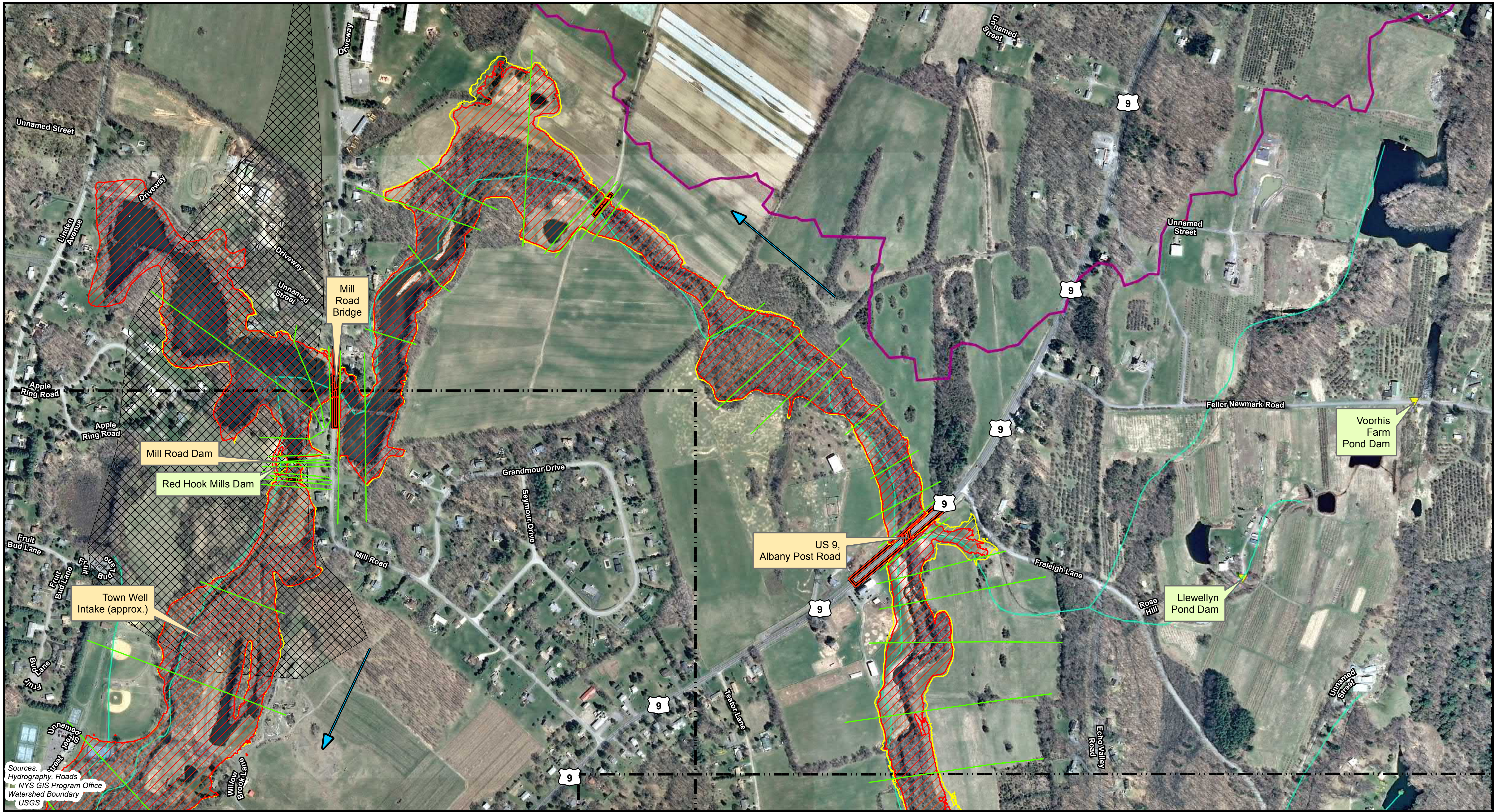


Figure 1-3: Inundation Map

Saw Kill Watershed

FUSS & O'NEILL

PROJ. No. 20161136.A1N

DATE: MARCH 2018

0 500 1,000 1,500 Feet

Legend:
- Existing Conditions 1% Annual Chance (100-Year) Flood Inundation Area (approx.)
- Future Conditions 1% Annual Chance (100-Year) Flood Inundation Area (approx.)
- Direction of Flow
- Representative Cross Sections
- Dam Crest
- Roadway Crossings
- Streams
- Well Recharge Areas
- Watershed Boundary
- Match Line
- Dams
- Flooding Locations

Path: K:\P2016\1136\A1N\MXD\SawKill_ExistingConditions_InundationMap.mxd

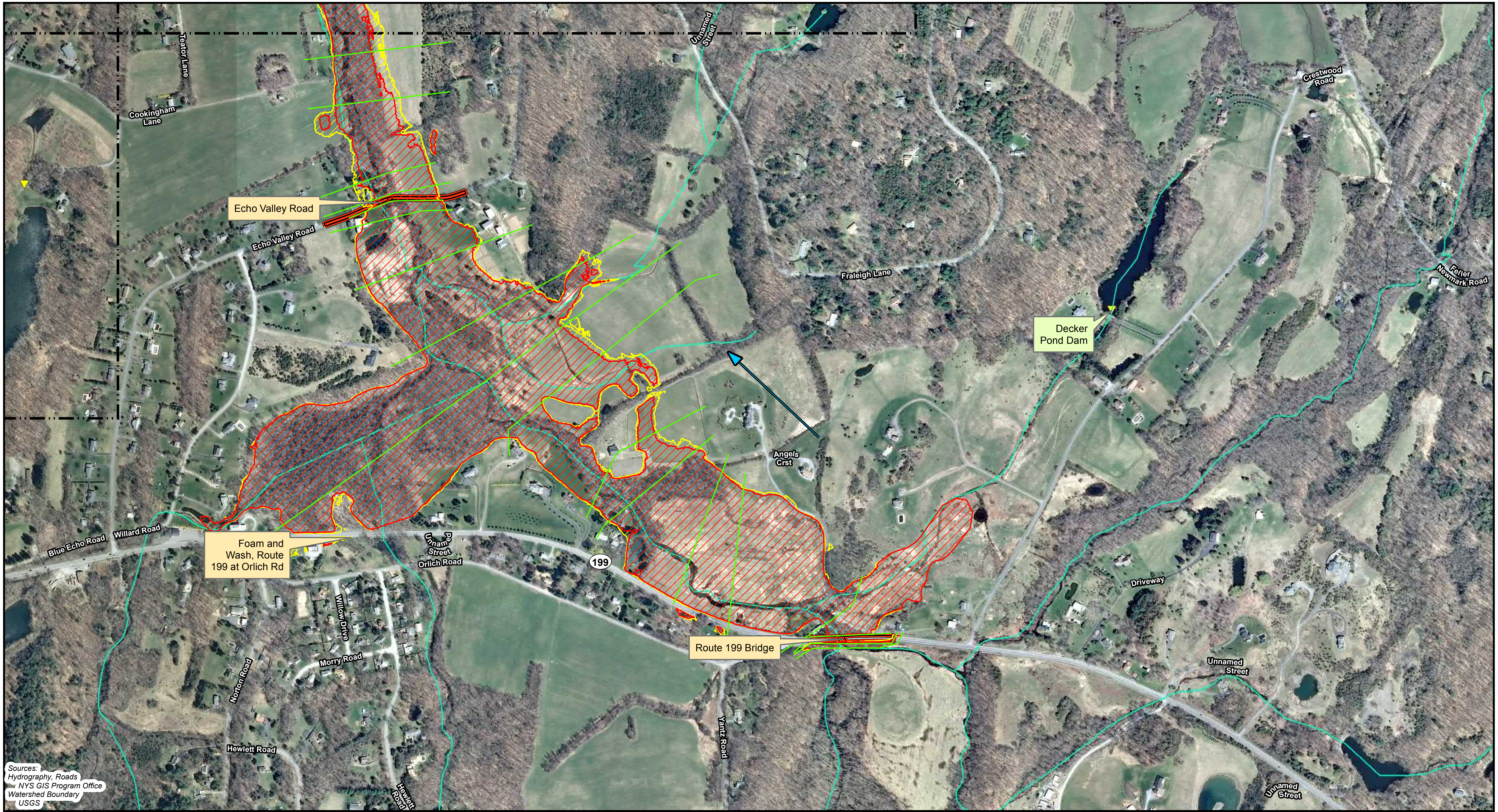


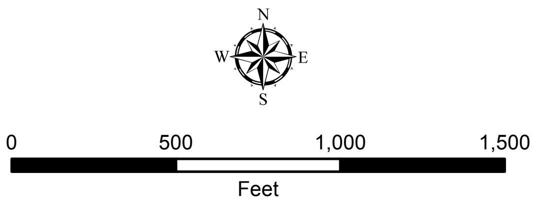
Figure 1-4: Inundation Map

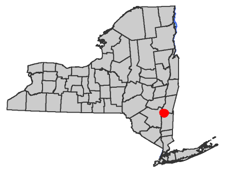
Saw Kill Watershed

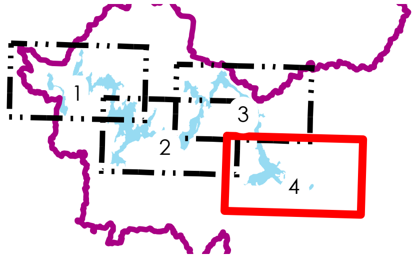
FUSS & O'NEILL

PROJ. No. 20161136.A1N

DATE: MARCH 2018







Existing Conditions 1% Annual Chance (100-Year) Flood Inundation Area (approx.)

Future Conditions 1% Annual Chance (100-Year) Flood Inundation Area (approx.)

Direction of Flow

Representative Cross Sections

Dam Crest

Roadway Crossings

Streams

Well Recharge Areas

Watershed Boundary

Match Line

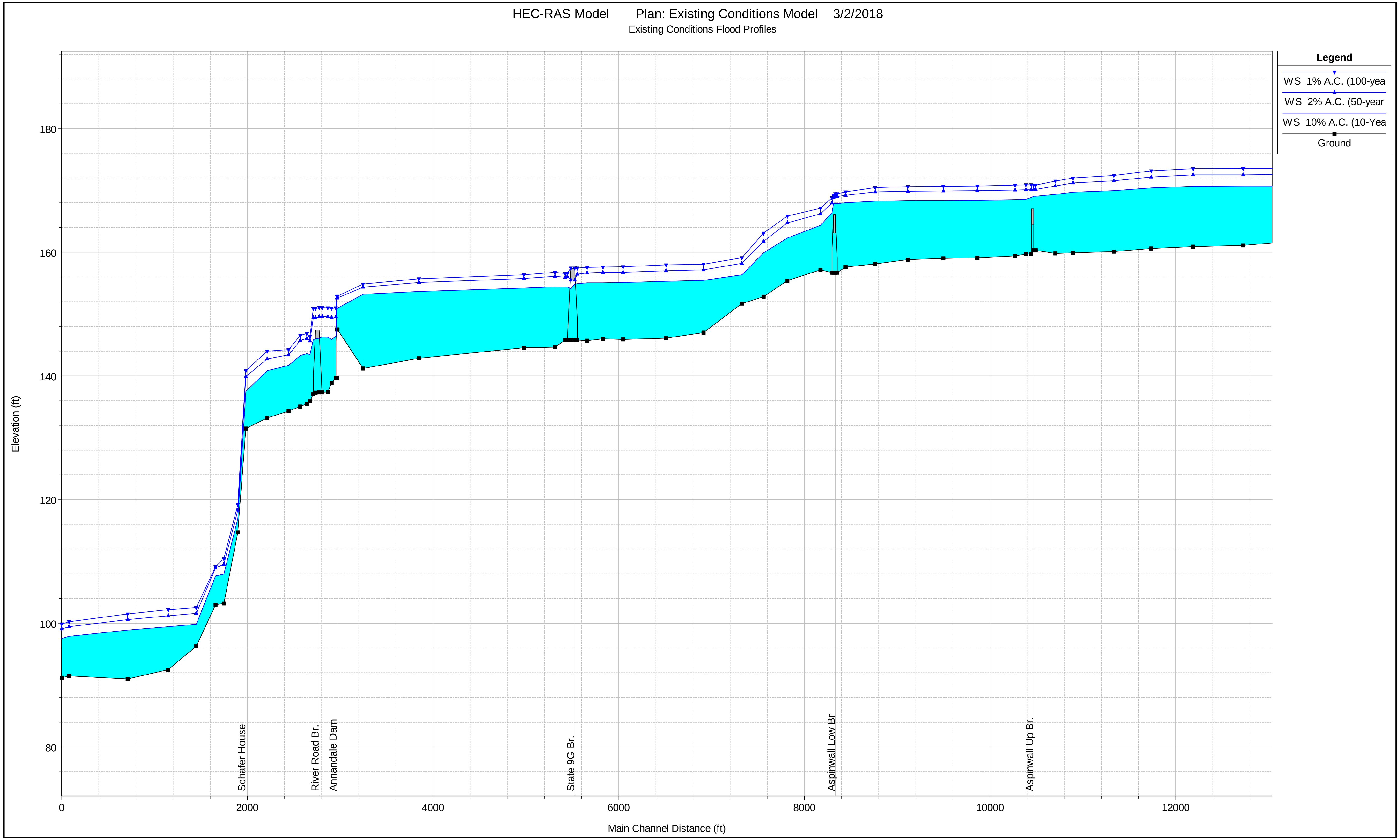
Dams

Flooding Locations

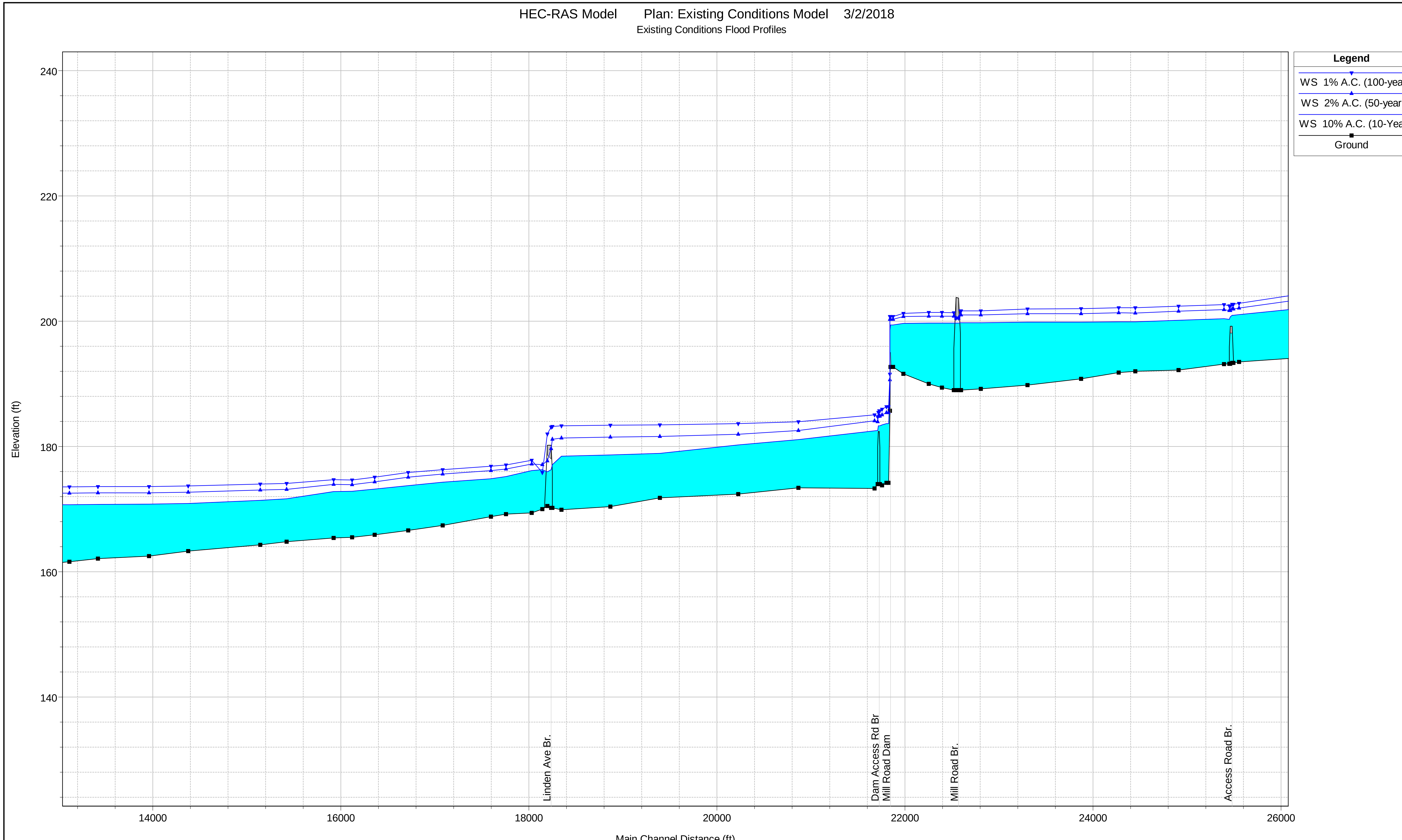
Path: K:\P2016\1136\A1N\MXD\SawKill_ExistingConditions_InundationMap.mxd

Appendix C

Existing Conditions Flood Profile



1 in Horiz. = 1000 ft 1 in Vert. = 15 ft



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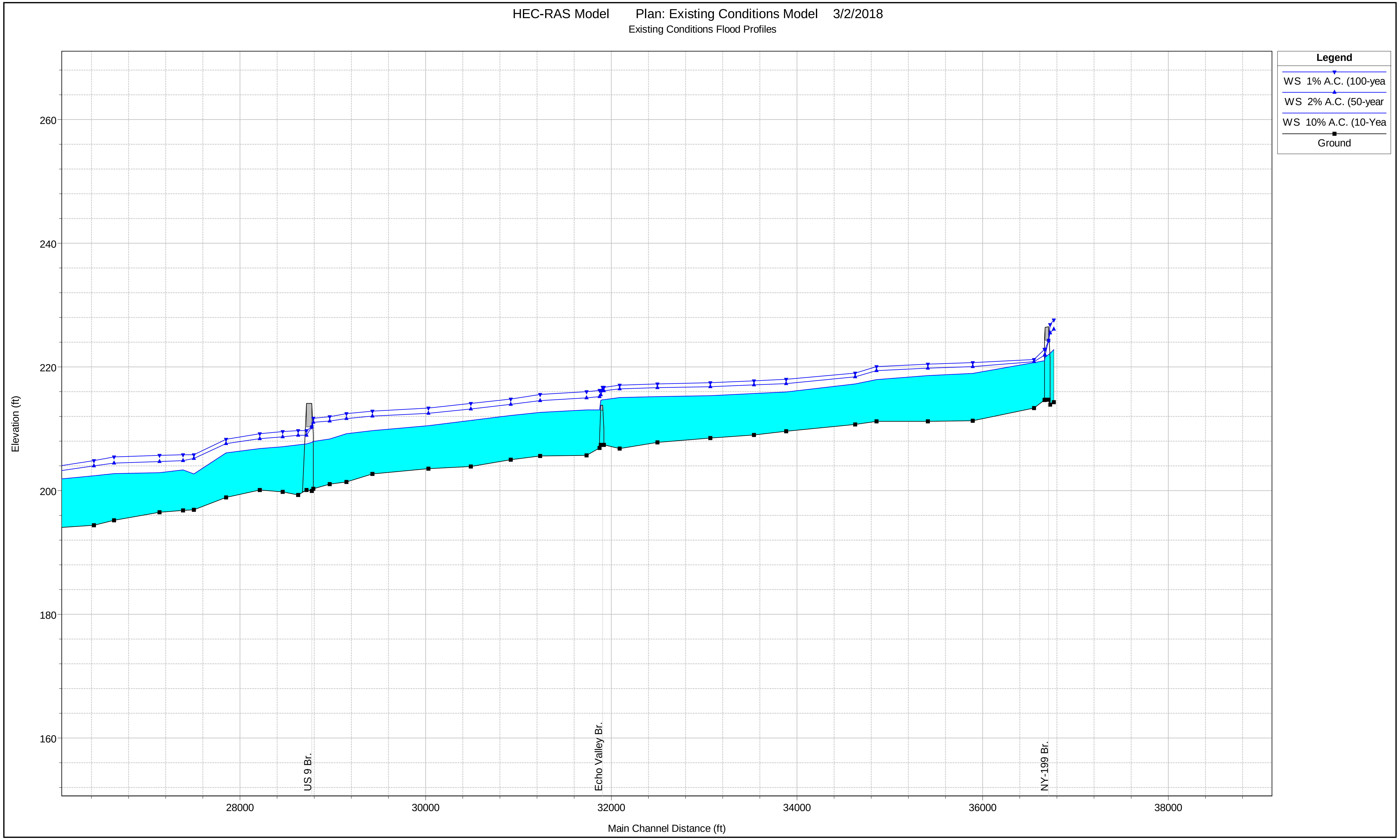
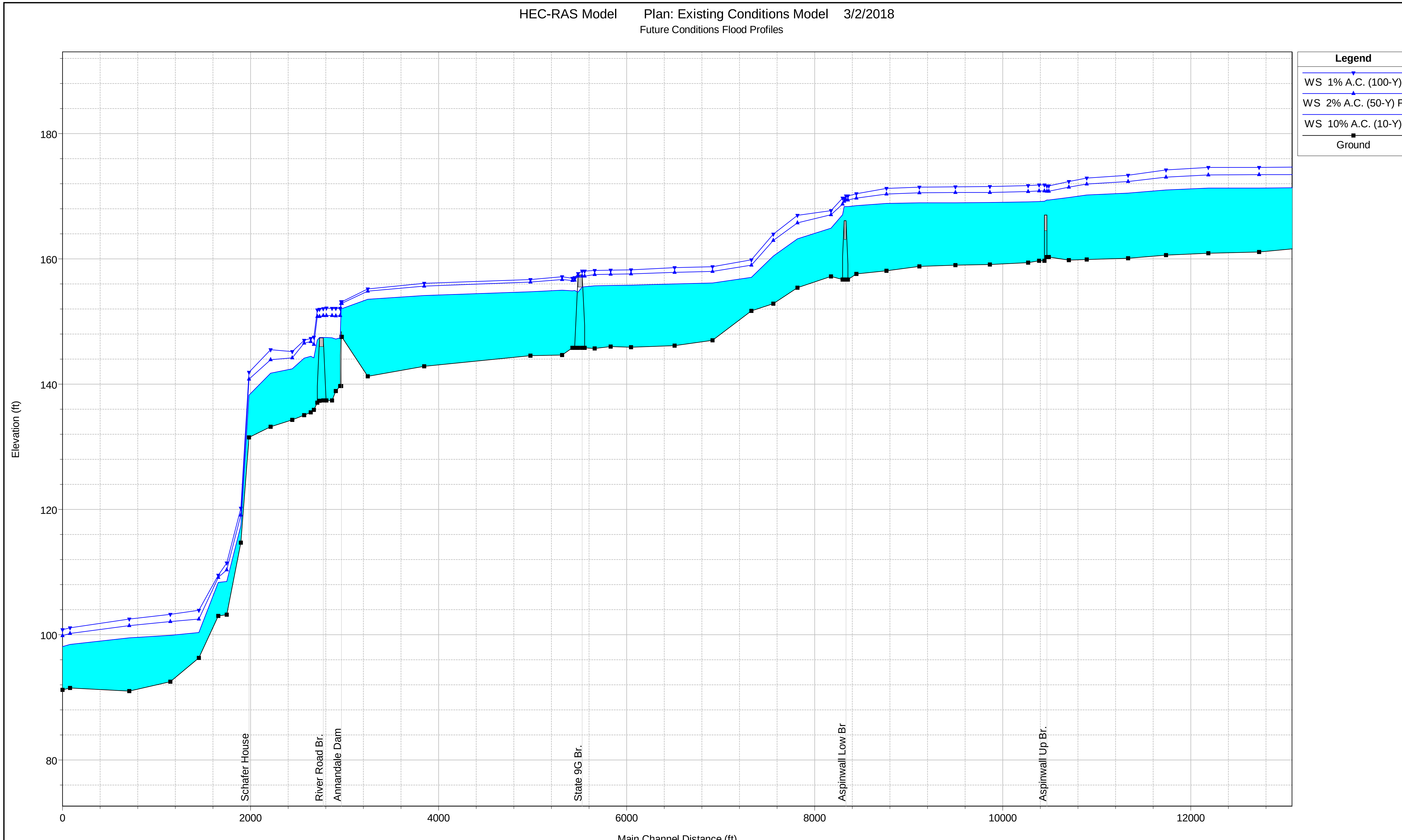


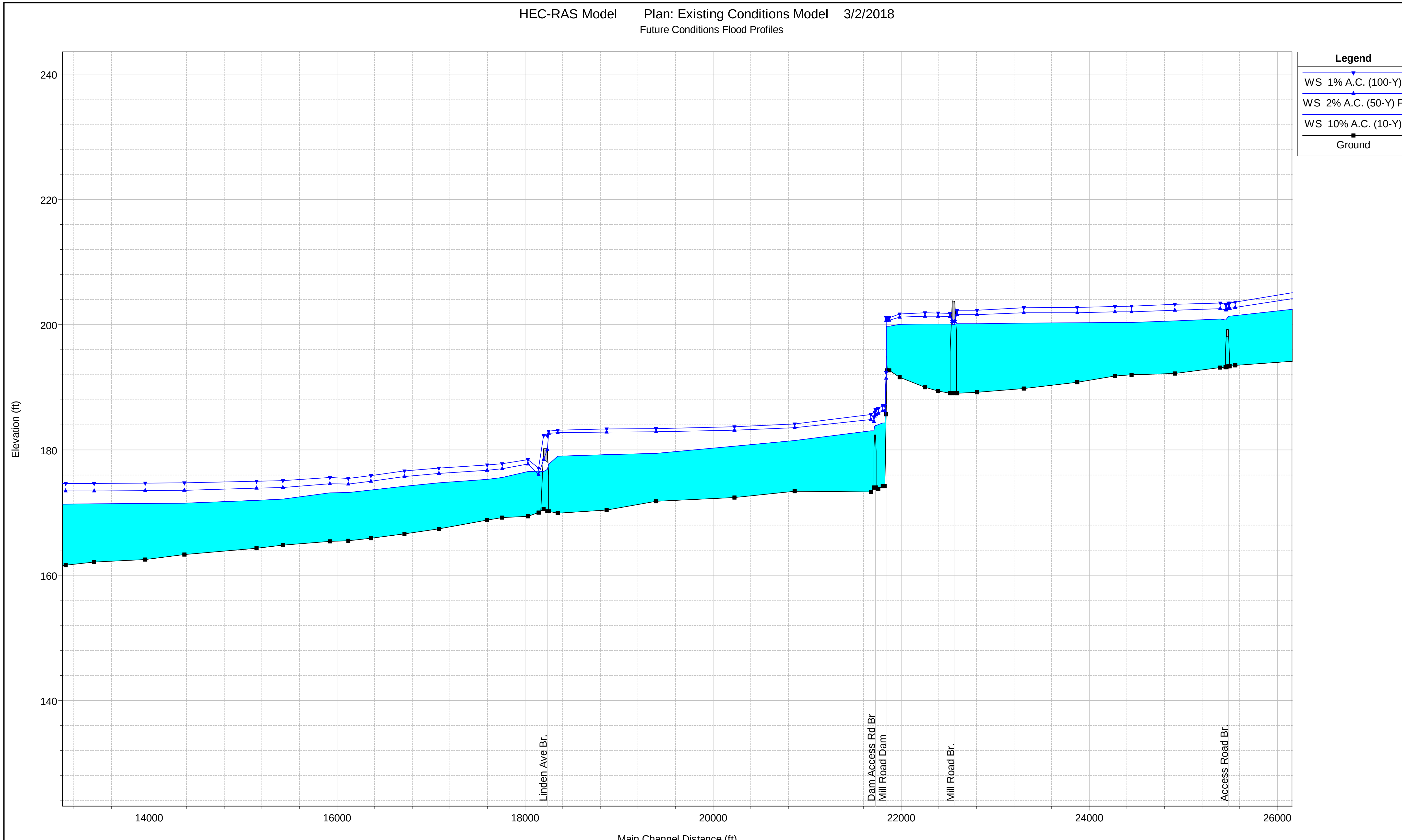
1 in Horiz. = 1000 ft 1 in Vert. = 15 ft

Appendix D

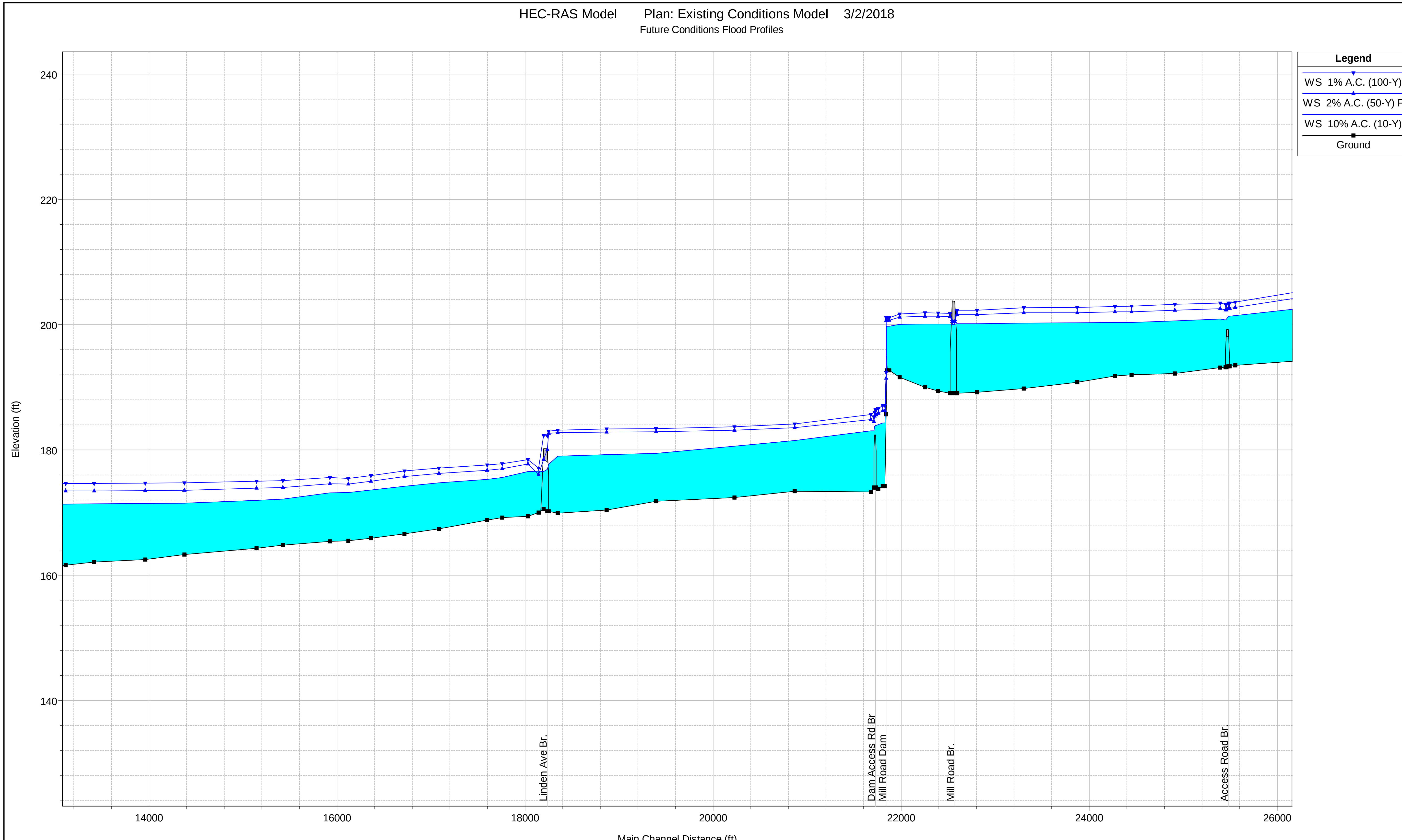
Future Conditions Flood Profile



1 in Horiz. = 1000 ft 1 in Vert. = 15 ft



1 in Horiz. = 1000 ft 1 in Vert. = 15 ft



1 in Horiz. = 1000 ft 1 in Vert. = 15 ft

Appendix E

Geomorphic Assessment Technical Memorandum (by Inter-Fluve)

TECHNICAL MEMORANDUM

To: Erik Mas, Fuss & O'Neill, Inc.

From: Candice Constantine and Nick Nelson, Inter-Fluve, Inc.

Date: November 14, 2017

Re: Task 4: Saw Kill Watershed and Flood Mitigation Assessment: Geomorphic Assessment and Recommendations

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Executive Summary

Inter-Fluve has partnered with Fuss & O'Neill to complete a flood mitigation assessment for the Saw Kill watershed in Dutchess County, New York. We combined a review of existing data and a targeted reconnaissance-level field assessment to characterize geomorphic processes occurring in the watershed and identify flood mitigation alternatives related to channel and floodplain geomorphology and function. Within the lower reaches of the Saw Kill from Annandale Dam upstream to NY State Highway 199, the channel is generally low gradient with bedrock controlling channel elevation in the vicinity of Annandale Dam. Floodplain width is variable and is limited in some places by terraces of glacial or alluvial materials. The channel and floodplain record a legacy of artificial modification including dredging, straightening, and clearance for agriculture, although riparian buffers have been re-established in many areas. In general, the channel where surveyed appears to be relatively stable, and current channel form is likely to have been influenced by the land-use history of the watershed. Based on our findings, we recommend a watershed-wide approach to flood risk management that includes removing artificial barriers or restrictions where possible, vegetating active floodplains and restoring natural river meanders to slow flood flows, protecting open spaces, increasing floodplain storage in upstream areas, and confining future vulnerable development types to higher ground. If problems with erosion or deposition are found in the future, we recommend developing sustainable approaches focused on resolving the sources of the problems and minimizing adverse impacts to in-stream habitat. Site-specific recommendations from our targeted field assessment include removal of Annandale Dam, including the management of 7,000 to 10,000 cubic yards of impounded fine sediment; re-activation of abandoned meanders immediately downstream of Mill Road Dam; increasing flood storage and expanding the riparian buffer at the Greig Farm property off of Rockefeller Lane; bridge replacement and channel stabilization at Echo Valley Road; and removal of the failed concrete dam on Battenfeld Road.

Introduction

BACKGROUND

Inter-Fluve has partnered with Fuss & O'Neill to complete a flood mitigation assessment for the Saw Kill watershed, an approximately 26 square-mile area located in Dutchess County of the mid-Hudson Valley region, New York. Inter-Fluve's role is to characterize the relevant geomorphic processes occurring in the watershed and identify flood mitigation alternatives related to channel and floodplain geomorphology and function. This technical memo summarizes our review of existing data, geomorphic field assessment, and recommendations.

ASSESSMENT SCOPE

The scope of the following assessment includes:

- Review of existing data including publicly available historical aerial photographs, GIS data, anecdotal information, and previous reports to develop an understanding of geologic context, watershed history, and basin-scale watershed processes;
- Completion of a field assessment to collect data in targeted areas and investigate reach-scale processes; and
- Identification of measures to improve flood resilience through the restoration of floodplain and stream channel form and function.

Figures and field data referenced or generated for this study are included in the following appendices:

- Appendix A – Existing Data;
- Appendix B – Figures; and
- Appendix C – Field Data Collection Sheets.

Existing Data Review and Basin-Scale Analysis

GEOLOGICAL SETTING

The Saw Kill watershed is largely underlain by folded clastic rocks of Ordovician age, primarily shales. The current landscape was shaped by repeated glaciations in the Pleistocene. Surficial deposits of recent (Holocene) alluvium (fine sand to gravel) can be found along valley bottoms bounded by terraces of material associated with Pleistocene glacial activity including till, kame deposits, outwash sands and gravels, and pro-glacial lacustrine silts and clays [Refer to Figure 4 of Technical Memorandum No. 1 - Field Assessments and Preliminary Analysis (Fuss & O'Neill, August 31, 2017), Appendix A]. Unit descriptions are provided below[1].

[1] http://www.nysm.nysed.gov/research-collections/geology/gis. Accessed September 23, 2017.

Recent alluvium – Oxidized fine sand to gravel. Permeable. Generally confined to floodplains within a valleys. In larger valleys, may be overlain by silt. Subject to flooding. Thickness 1-10 meters.
Till – Variable texture (boulders to silt), usually poorly sorted sand-rich diamict. Deposition beneath glacier ice. Permeability varies with compaction. Variable thickness (1-50 meters).
Kame deposits – Coarse to fine gravel and/or sand, includes kames, eskers, kame terraces, kame deltas, ice contact, or ice cored deposition. Lateral variability in sorting, texture and permeability. May be firmly cemented with calcareous cement. Variable thickness (10-30 meters).
Outwash sand and gravel – Coarse to fine gravel with sand. Proglacial fluvial deposition. Well-rounded and stratified, generally finer texture away from ice boarder. Permeable. Variable thickness (2-20 meters).
Lacustrine silt and clay – Generally laminated silt and clay, deposited in proglacial lakes. Generally calcareous. Low permeability. Potential land instability. Variable thickness (up to 50 meters).

Near-surface bedrock is mapped beneath the channel upstream of Annandale Dam in the lower watershed and at higher elevations.

LAND USE / LAND COVER

Current land cover in the watershed was reported by Fuss & O'Neill (2017) with forests and wetlands comprising more than 60% of the watershed. Many stretches of the river and its tributaries currently have riparian buffers of forest and wooded wetland that provide shade, help to stabilize banks, provide a source of large wood to the system, and help to protect the watercourses from the impacts of adjacent land uses.

A qualitative review of historical aerial photos[2] shows that the extent of forest cover in the watershed has increased significantly since the 1930s when land was farmed right up to the river's edge in many places. Generally, there has been a shift in land use from agriculture (pasture and cropland land cover types) to residential (developed and forested land cover types).

FLOOD AND CHANNEL DYNAMICS

The lower reaches of the Saw Kill from Annandale Dam upstream through NY State Highway 199 are relatively low gradient, with an average channel slope of approximately 10.5 ft/mile or 0.002[3]. This low-gradient extent encompasses many of the areas susceptible to flooding identified by Fuss & O'Neill and the project partners in an earlier phase of the project [Refer to Figure 2 of Technical Memorandum No. 1 - Field Assessments and Preliminary Analysis (Fuss & O'Neill, August 31,

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[2] http://geoaccess.co.dutchess.ny.us/aerialaccess/. Last accessed September 24, 2017. Photos available from 1936 to 2014.
[3] Refer to USGS Stream Stats report in Appendix A

2017), Appendix A]. Two dams are present along this length of the river, the Annandale and Mill Road Dams, which were both constructed at locations where bedrock was exposed by the river bed. The dams impound low flows, affect higher magnitude flood profiles and dynamics, act as barriers to aquatic organism migration and sediment flux, and affect water quality. Both structures were included in an initial Hudson River Estuary barrier removal feasibility study carried out by The Chazen Companies in 2016. Bard College, owner of the Annandale Dam, is considering dam removal as an option to restore the site to a more natural condition and eliminate liability. According to The Chazen Companies (2016) report, the owner of the Mill Pond Dam is supportive of removal to reduce flooding of his own and others' property upstream of the dam but is concerned about opposition from neighbors who would lose waterfront if the impoundment is eliminated.

Where topographic maps and FEMA flood zones show a wide floodplain, the channel is typically single-threaded and sinuous. A notable exception is immediately downstream of Mill Road Dam (Figure 1). From historical aerial photographs, the river here appears to have been artificially straightened in the 1950s (Figure 2). Images from 1936 and the 1940s, around the time when the dam was constructed, show a sinuous channel and an oxbow lake in the floodplain, evidence of active meander migration processes. The area is within the Town of Red Hook's groundwater wellfield recharge area and includes a pump station at the end of Willowbrook Lane. A dredged high-flow channel connects the river to a pond adjacent to the Town's wellfield. Both the channel and pond are thought to have been created for agricultural purposes prior to establishment of the wellfield in 1985-86[4]. In 2000-01, the Town installed a filtration system to filter out organics found in the well water, which were thought to be derived from the pond[4]. The Saw Kill itself is thought to be a gaining stream in this reach (i.e., groundwater discharges into the stream from surrounding uplands), and there is no evidence that well water quality is linked to surface water quality within the river[4].

Other reaches of reduced sinuosity occur where the floodplain narrows between terraces such as immediately upstream of Aspinwall Road and again at Greig Farm (Figure 1). Inspection of historical photographs shows relatively little planform change (i.e., change in the position or pattern of the river channel in map view) even within sinuous reaches since the 1930s and 40s. This observation is supported by the fact that stakeholders had no particular concerns about active erosion, deposition, or bank failures along the river. In a follow-up conversation with the Town of Red Hood Highway Department, the observation was made that the width and depth of the river have decreased in recent decades[5].

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[4] Hank Van Parys, Chair, Town of Red Hook Water Department, personal communication, September 26, 2017.
[5] Rick Schloemer, Deputy Highway Superintendent, personal communication, July 18, 2017.

ANNANDALE DAM

The preliminary dam removal feasibility work completed by The Chazen Companies (2016) included 12 spot measurements of impounded sediment depth and chemical analysis of one sediment sample. The results suggest that a limited volume of fine sediment has accumulated within the main channel upstream of the dam (200 to 1,000 cubic yards). This estimate excludes impounded sediment that has been colonized by vegetation, largely emergent wetland species. Figure 3 shows the approximate extent of the impoundment that has been filled in and colonized, confirmed by field inspection and analysis of topographic data. Chazen found bedrock or boulders within the bed of the channel at the bend immediately upstream of the dam and concluded that little headcutting would occur as a result of removing the Annandale dam structure.

Chazen conducted limited chemical analysis of a sediment sample taken from an area of established wetland within the impoundment and concluded that it may be possible to class the sediment as Class A – No Appreciable Contamination (No toxicity to aquatic life) (NYS DEC, 2004). Class A sediment can generally be dredged or reused on site. Further sampling and analysis would be required to confirm this.

Geomorphic Field Assessment

Based on the existing data review and discussions with stakeholders and Fuss & O'Neill, we targeted pre-selected sites for closer field inspection (Figure 4). An Inter-Fluve geomorphologist and engineer conducted field surveys on August 31 and September 1, 2017. Observations made and data collected in the field are summarized below, with the details and photos in the field data collection sheets included as Appendix C. Sites are listed below in order from downstream to upstream. References to right and left bank are from the perspective of looking downstream.

ANNANDALE DAM

To further the dam removal feasibility work previously completed for the Annandale Dam, we carried out a more detailed bathymetry and depth of refusal survey within the impoundment to facilitate sediment management planning and clarify the potential impacts to surrounding infrastructure. The survey was carried out on August 31, 2017 using a real-time kinematic (RTK) satellite receiver and survey rod to collect positional data. Data were collected in the State Plane New York East (feet) projection relative to the NAD 83 datum. Sediment depths were probed using a threaded, stainless steel rod marked in 0.1-foot increments. Depths of impounded fine sediment and the likely composition of the refusal layer were recorded. A map of the data points collected is shown in Figure 5.

We observed minimal fine sediment accumulation on the outside of the primary meander bend making up the impoundment, or approximately 800 feet upstream of the dam; however, impounded sediment depths of 4 feet or more were recorded along the inside of the bend and farther upstream.

Just upstream of the bend, there is a tree growing within the channel, causing elevated local depths of sedimentation along the thalweg, or the deepest point in the channel. Average impounded sediment depths reduce with distance upstream until approximately 200 feet downstream of the Route 9G bridge where boulders and cobbles can be seen along the channel bed. Bedrock was observed beneath the Route 9G bridge itself and along the channel bed immediately upstream of the bridge. The influence of the dam on the low-flow water surface profile extends an additional approximately 1,400 feet upstream of the Route 9G bridge to a riffle and bedrock seam.

Longitudinal profiles of the channel bed surface and depth of refusal surface are shown in Figure 6. The water surface shown is reflective of low-flow conditions; flow on the day of the survey overtopped the dam spillway by about 0.1 foot. Based on the new data collected, we estimate that the volume of impounded fine sediment contained within the channel limits is approximately 7,000 to 10,000 cubic yards. Although the thalweg and outside bank of the meander bend are largely free of accumulated material, a significant volume of sediment is being stored in other areas of the channel and may be mobilized following dam removal. This is illustrated by a cross section taken approximately 265 feet upstream of the dam (Figure 7). Limited downcutting of the thalweg following dam removal is anticipated due to the presence of bedrock and other competent material present throughout the impoundment and upstream through the Route 9G bridge.

In addition to surveying the impoundment, we collected measurements at a typical cross section upstream of the influence of the dam in order to provide an indication of design parameters for the restored channel following dam removal. We walked the channel immediately upstream of the downstream Aspinwall Road crossing (see inspection point on Figure 5) and located a typical cross section outside the hydraulic influence of the bridge. The bankfull channel is approximately 35 feet wide and 4.3 feet deep. On the day of the survey, the water depth was approximately 1.8 feet deep. The bed locally is composed of boulders, cobbles, and a lot of fines, apparently deposited as a result of a low-flow backwater effect caused by an outcrop of bedrock in the bed of the channel downstream. These measurements are consistent with others collected along the main channel of the river (see following sections).

Aquatic habitat within the impoundment is limited to areas of cover around pieces of large wood that have fallen into the impoundment. Upstream and downstream of the impoundment, the varied channel substrate and water depth provide a variety of habitat opportunities. Within the impoundment, however, this substrate and depth complexity is reduced due to infilling of sand and fine sediment and growth of aquatic vegetation.

UPSTREAM ASPINWALL ROAD BRIDGE

We walked the river for a distance of 1,150 feet upstream of the upstream Aspinwall Road bridge (see Figure 4) to inspect an area where the floodplain is confined between terraces (Appendix C). The channel in this location appears stable with no evidence of aggradation, incision, or ongoing bank erosion except immediately upstream of the bridge where flood flows backing up behind the structure have caused local scour of the banks and a widened cross section. Elsewhere, the typical bankfull width is approximately 29 to 33 feet, and bankful depth is approximately 3 to 4 feet. Rock armor is exposed at the base of the banks in some places and appears to be the source of angular cobbles composing the bed. The river in this area is very low gradient such that small features on the bed cause low flows to back up behind them, having a noticeable effect on flow dynamics and bed composition. In this particular reach, a property owner has constructed a small dam of boulders and cobbles that slows and deepens upstream flows and has resulted in deposition of a lot of fine material on the bed surface. The source of the fines is likely the surficial lacustrine deposits mapped in this area.

Aquatic habitat is limited in this reach to primarily the areas around pieces of large wood that have fallen into the channel. Around the large wood, sediment is deposited upstream and pools have scoured downstream. No other bedforms are present.

MILL ROAD DAM

We included the channel downstream of Mill Road Dam (shown in Figure 2) in our field assessment (see field data sheet in Appendix C) in order to investigate the potential for restoration of this artificially straightened reach. The straightened reach has been dredged and is overly deep with a bankfull width of 48 feet and a bankfull depth of 5 feet. The bed is sand and gravel, but no bedforms are present until 1,350 feet downstream of Mill Road Dam where the dredged reach ends, the channel narrows, and a riffle is present (bankfull width of the riffle is 34 feet).

The channel flows along the toe of a terrace, so no floodplain is present along the right bank. On the left bank, however, a wide floodplain with relic meandering channels is preserved (Figure 8). In one location, a relic channel is approximately 20 feet wide and 2.5 feet deep with cobbles and gravel present on the former river bed. Cutting across the floodplain is a high-flow intake channel that feeds a pond located adjacent to the Town wellfield (Figure 9).

While canopy cover is sufficient in this reach, aquatic habitat opportunities are limited to the few instances of large wood that has fallen into the channel, creating localized scour and complexity. Small fish were observed in these areas of cover.

GREIG FARM (ROCKEFELLER LANE)

We visited an area of Grieg Farm off of Rockefeller Lane to inspect a narrow section of floodplain for signs of channel incision or instability and to investigate the potential for implementation of measures such as additional flood storage or widened riparian buffer in this reach (Appendix C). The site is located on a broad meander bend immediately upstream of the Mill Road Dam impoundment (Figure 1). The floodplain in this reach is narrow and bordered by alluvial terraces which are actively farmed down to the narrow riparian buffer. Bankfull width is approximately 35 feet and bankfull depth is about 3.5 feet. The bed is composed of sand to cobbles with some riffle-pool sequences present, longitudinal substrate variability, and active sediment transport. There are some undercut banks and evidence of minor lateral erosion, which provides a source of the rounded cobbles and gravel making up the streambed. The farm fields on either side of the channel rise in elevation away from the river, with the fields on river left, or the inside of the bend, rising more gently.

Aquatic habitat in this reach is sufficient and varied. Overhead canopy and bank vegetation provides shade and immediate cover over large portions of the channel. Substrate complexity and depth variability provide a wide variety of habitat opportunities for macroinvertebrates, fish, and other aquatic organisms. Large wood and boulders provide additional habitat complexity.

ECHO VALLEY ROAD

The Echo Valley Road crossing was included in our assessment as a known location where the channel is constricted and regular flooding occurs. We measured channel dimensions a short distance upstream of the bridge and found that bankfull width and depth are approximately 20 feet and 2 feet. The proximal floodplain is low-lying and heavily vegetated on the left bank. The channel bends sharply left and then right to pass through the bridge, directing flow toward the left bank along a downstream property. The downstream, left bank property owner met us on site at the time of the survey and stated that he had lost land from erosion since the new bridge was constructed on a skew. Beaver activity immediately upstream of the bridge is currently impounding low flows.

BATTENFELD ROAD

In the upper watershed, we targeted Battenfeld Road [Refer to Figure 2 of Technical Memorandum No. 1 - Field Assessments and Preliminary Analysis (Fuss & O'Neill, August 31, 2017), Appendix A, for location] to examine a relic dam and undersized culvert along the main channel (Figure 10). The concrete dam has failed but the pieces of the structure remain in the channel restricting flow. A small wetland exists upstream of the structure where the former impoundment filled in and was colonized by vegetation. Downstream, the channel bed is composed of bedrock, boulders, and cobbles, and flow appears to be intermittent.

Recommendations

Overall, the gradient of the lower reaches of the Saw Kill is so low that small blockages or high spots on the bed cause backwater effects, limiting in-stream habitat complexity and encouraging the accumulation of fine sediment during low flows. During floods, these small barriers are likely overwhelmed by larger features such as dams and bridges dominating the flood profile. The floodplain available for flood storage is limited in some places by terraces of glacial or alluvial materials. In specific areas, the channel has been artificially modified for agricultural or other purposes and some of the natural form and function of the river has been lost. Throughout the watershed, intensive agricultural land use extending down the river's edge has transitioned in recent decades towards more residential land use with forested and wetland cover types, including the establishment of riparian buffers. In general, the channel appears to be relatively stable with no evidence of excessive erosion or deposition in the areas surveyed, although the current channel form may be the legacy of the land-use history of the watershed.

Based on our findings, we recommend a watershed-wide approach to flood risk management that includes removing artificial barriers or restrictions where possible, vegetating active floodplains and restoring natural river meanders to slow flood flows, protecting open spaces, increasing floodplain storage in upstream areas, and confining future vulnerable development types to higher ground. If areas of bank instability or excessive erosion or deposition are discovered, the causes should be investigated and appropriate measures developed. We recommend developing sustainable approaches that target the cause of the problem and minimize adverse impacts to in-stream habitat (for example, slope stabilization or alteration of land management practices instead of repeat dredging operations to deal with excessive sedimentation). Site-specific recommendations following from our targeted field assessment are outlined below.

ANNANDALE DAM

Removal of the Annandale Dam is recommended as part of a comprehensive approach to flood risk management in the watershed. While it is reasonable to expect that dam removal will help to reduce flood risk to immediate upstream properties, modeling is required to quantify the benefits. The dam is a good candidate for removal because of the low risk to infrastructure. Data collected for this study suggests that 7,000 to 10,000 cubic yards of fine sediment is being stored in the channel through the impoundment and would be susceptible to mobilization if the dam is removed. Where this material currently occupies the thalweg, it may be possible to excavate it and re-use it on site subject to further sampling and testing in conformance with state guidelines. Elsewhere, bank stabilization methods could be used to stabilize sediments exposed following dam removal and establish a restored, narrower channel with dimensions similar to those documented upstream of the influence of the impoundment. Stabilization measures and/or planting may also be necessary in existing vegetated wetland areas through the impoundment to facilitate the transition to new upland floodplain. Bedrock, boulders, and cobbles were mapped along much of the impoundment channel thalweg, suggesting that thalweg adjustment following dam removal would be limited and confined to the area downstream of the Route 9G bridge.

In the event of dam removal, we would anticipate rapid recovery of habitat complexity within the impoundment. The next steps in the project would be to carry out further sediment sampling and analyses and complete permit-ready designs, including design of stabilization measures and development of a sediment management plan, and to begin the permitting process.

UPSTREAM ASPINWALL ROAD BRIDGE

Because of the natural topography of the area, very little can be done in this reach to increase floodplain storage. Removal of artificial flow restrictions such as the landowner dam would help alleviate local flooding; bridge replacement is being considered separately by Fuss & O'Neill. Removal of small obstructions like the landowner dam may help reduce flooding during low magnitude events but is unlikely to have a significant impact on large floods.

MILL ROAD DAM

Immediately downstream of Mill Road Dam, we recommend re-activating the former meandering channel as the primary channel during low to medium flows. As a part of this work, it may be beneficial to fill the existing high-flow connector channel and pond. Options for the existing dredged channel should be explored, including filling or retaining some capacity to convey flood flows. The restored channel alignment would need to take into consideration the Town's wellfield which was established after the channel was straightened.

The benefits of re-activating the meandering channel would be to slow flows by introducing roughness, reconnect the floodplain for flood storage and detention and to improve the quality of in-stream habitat by increasing flow and geomorphic complexity.

The feasibility of reactivating the former channel alignment would need to be considered further in discussion with the affected landowners (parcel 134889-6273-00-514250-0000, Silvio Bertolini and Franca Cooper; parcel 134889-6273-00-462170-0000, the Town of Red Hook; and parcel 134889-6273-00-557128-0000, Cookingham Farms, Inc.).

GREIG FARM (ROCKEFELLER LANE)

At the Greig Farm property off of Rockefeller Lane, a few options exist for improving the riparian corridor and helping to attenuate floods. First, the riparian buffer could be increased to cover the 500-year floodplain extents on the farm's land, which is already partly protected by a conservation easement (Red Hook Town Board, 2016). The total area of riparian buffer planting could be up to 15 acres as shown in Figure 11 and corresponds with an area mapped in a Town pilot project as "high priority" for the establishment and protection of habitat connectivity (AKRF and Greenplan, 2014). A tree planting project here may be eligible for assistance through the NYS Department of Environmental Conservation's Trees for Tribs program.

A second option at the site may be to increase flood storage by regrading and planting existing upland areas to create additional forested floodplain at a lower elevation. A candidate area is shown in Figure 12. Regrading within the existing 100-year floodplain extent could also increase flood storage during lower return period events (i.e. 25-year or 50-year events).

As a first step, hydraulic modeling would be required to test the effectiveness of these options and whether additional flood storage at this location would have an effect on peak flows and flood risk in priority areas.

ECHO VALLEY ROAD

The primary concern at this location is the angle of the stream as it approaches the bridge. This could be addressed through bridge replacement and road realignment (to be investigated separately by Fuss & O'Neill), or the upstream channel could be reconstructed with a stable bed and banks in a more appropriate alignment. It appears that channel obstructions immediately upstream of the bridge have resulted in channel adjustment. These obstructions could be removed and the channel stabilized along with the replacement of the bridge to minimize the risk of obstructions forming in the future.

BATTENFELD ROAD

At this site, removal of the failed concrete dam would be an appropriate measure to help prevent flooding of the adjacent roadway during a large storm. Some minor regrading of the wetland area upstream of the dam may be necessary to minimize the risk of mobilizing sediment that may block downstream culverts.

References

AKRF, Inc. and Greenplan, Inc., 2014. Planning for Resilient, Connected Natural Areas and Habitats: A Conservation Framework. A pilot project conducted by the Town of Red Hook, Village of Red Hook, and Village of Tivoli. December 15, 2014.

Brinnier & Larios, P.C., 2015. Topographic Survey of Montgomery Place Historic Hudson Valley Annandale Dam, NYS Dam ID 210-0898. July 2015.

The Chazen Companies, 2016. Owner Outreach and (Mitigation) Design of Priority Hudson River Estuary Biologically Important Barriers. Prepared by The Chazen Companies for the Hudson River Estuary Program, New York State Department of Environmental Conservation, in cooperation with the New England Interstate Water Pollution Control Commission. December 21, 2016.

New York State Department of Environmental Conservation (NYS DEC) Division of Water, 2014. Technical Operational Guidance Series (TOGS) 5.1.9. In-Water and Riparian Management of Sediment and Dredged Material. November 2004.

Red Hook Town Board, 2016. Community Preservation Plan Update, Town of Red Hook, Villages of Red Hook and Tivoli. Adopted June 9, 2016.

Appendix A – Existing Data

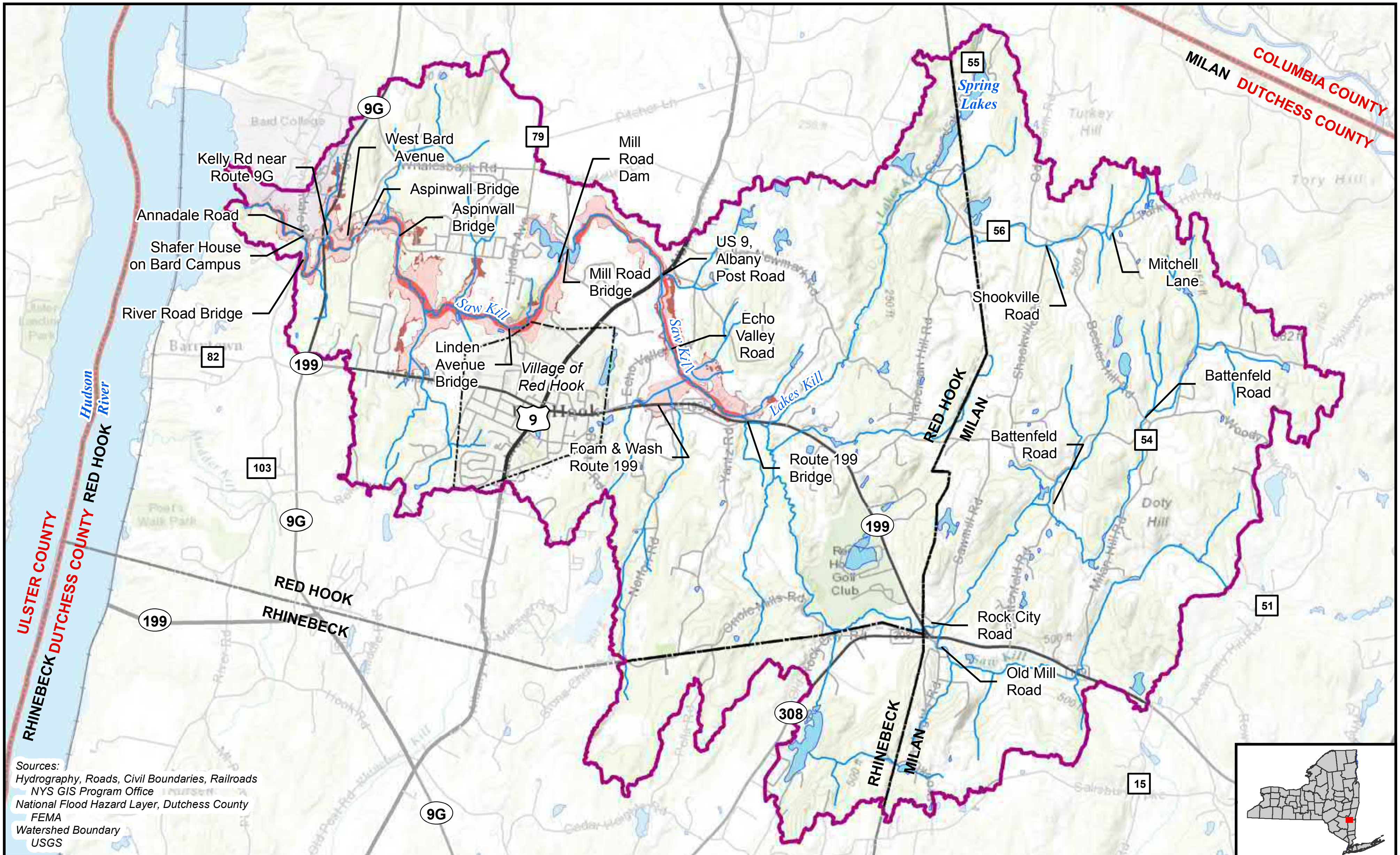


Figure 2: Areas Susceptible to Flooding and Flood Hazard Zones

Saw Kill Watershed

FUSS & O'NEILL

PROJ. No. 20161136.A1N

DATE: AUGUST 2017

0 0.5 1
Miles

FEMA Flood Zone

- 100-yr Flood Zone
- Regulatory Floodway
- 500-yr Flood Zone

- Streams / Rivers
- Surface Water
- Watershed Boundary
- Areas of Reported Flooding

Path: K:\P2016\1136\A10\MXD\Watershed-wide Maps\Sawkill_Watershed_FEMA_Zones_20170831.mxd

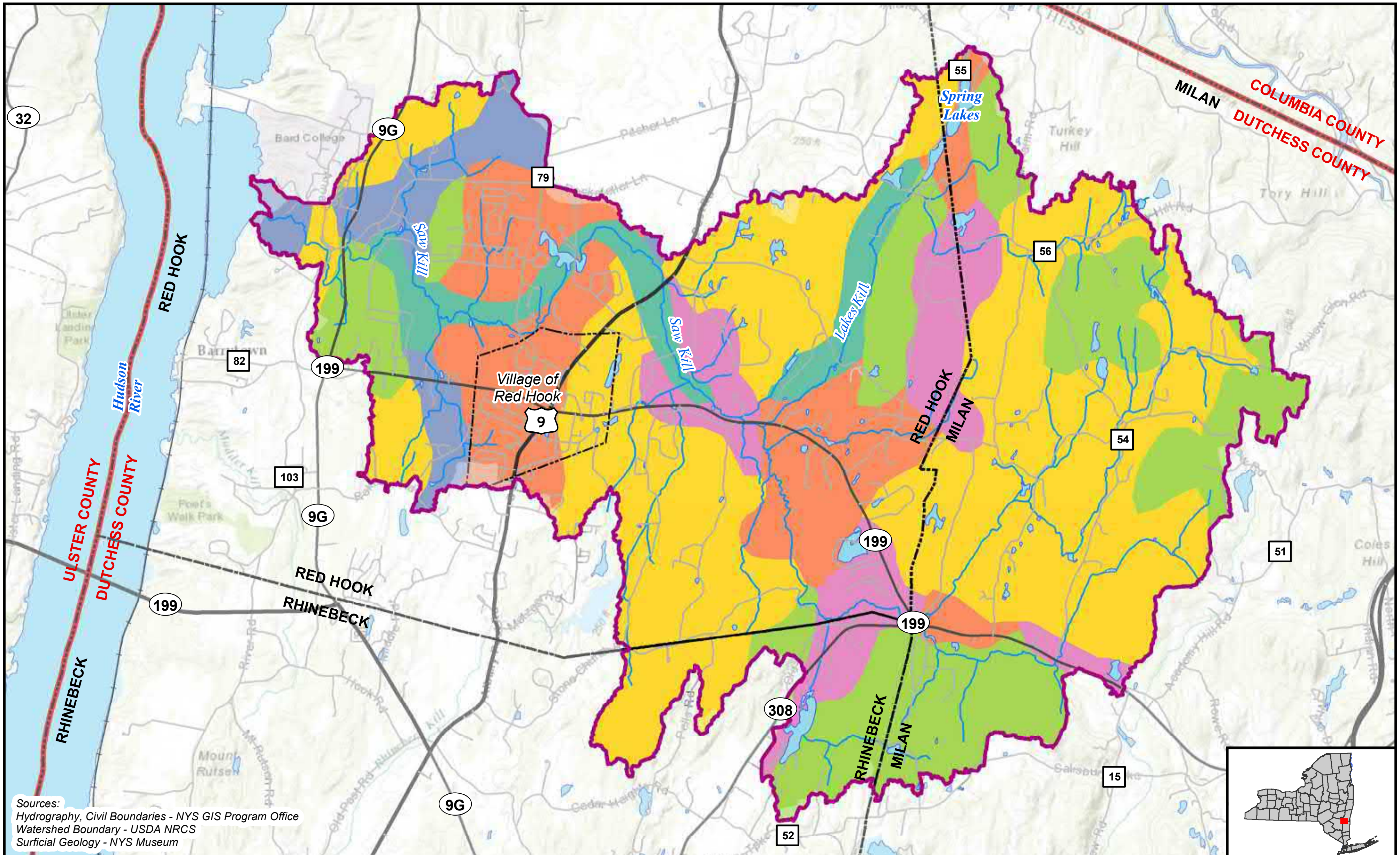


Figure 4: Surficial Geology

Saw Kill Watershed

FUSS & O'NEILL

PROJ. No. 20161136.A1N

DATE: AUGUST 2017

0 0.5 1 1.5
Miles

- Watershed Boundary
- Towns
- Counties
- Villages
- Surface Water
- Streams

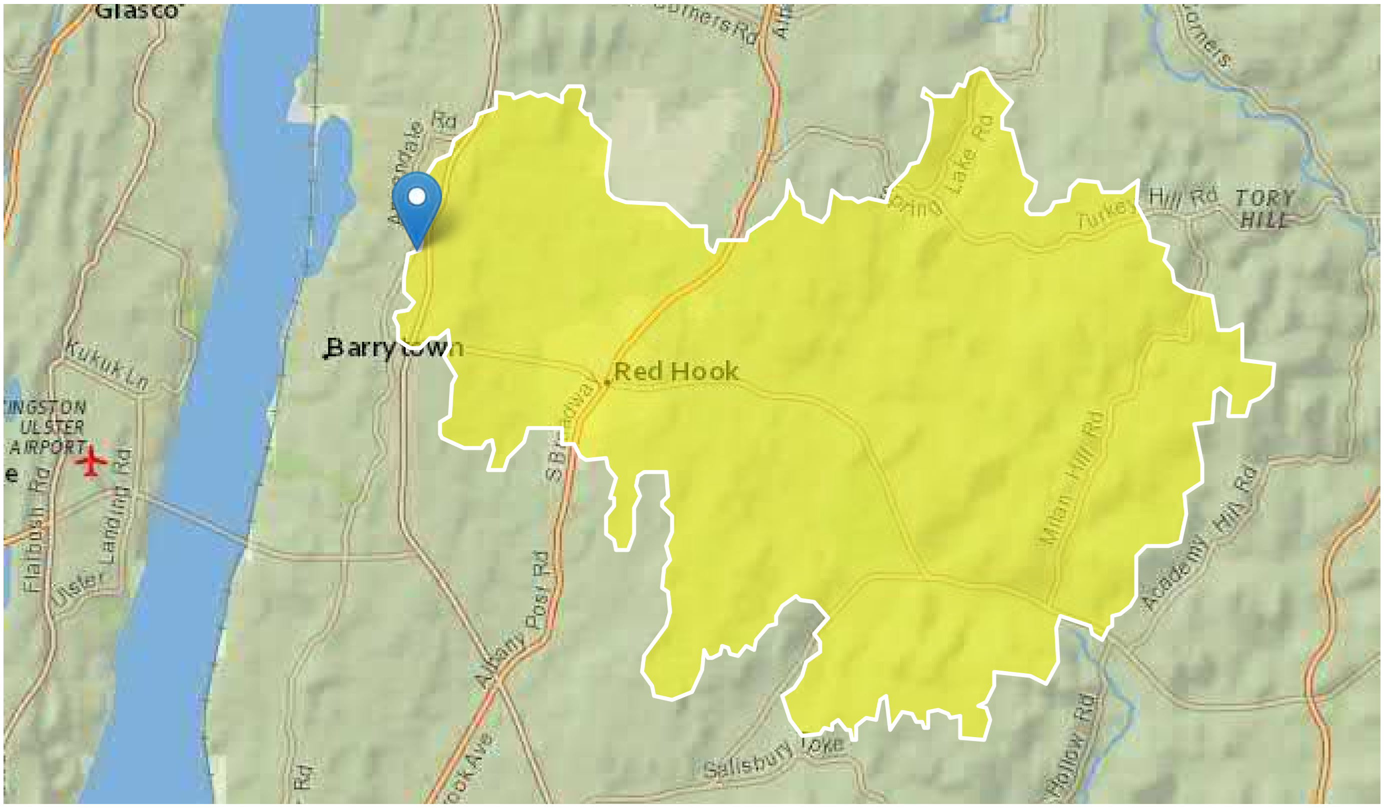
Parent Material

- Recent Alluvium
- Kame Deposits
- Lacustrine Sand & Gravel
- Outwash Sand & Gravel
- Bedrock
- Till

Path: K:\P2016\1136\A10\MXD\Watershed-wide Maps\Sawkill_SurficialGeology.mxd

StreamStats Report Saw Kill

Region ID: NY
Workspace ID: NY20170922181530614000
Clicked Point (Latitude, Longitude): 42.01174, -73.90861
Time: 2017-09-22 14:15:46 -0400



Basin Characteristics

Parameter Code	Parameter Description	Value	Unit
BSLOPCM	Mean basin slope determined by summing lengths of all contours in basin mulitplying by contour interval and dividing product by drainage area	402	feet per mi
CSL1085LO	10-85 slope of lower half of main channel in feet per mile.	10.5	feet per mi
CSL1085UP	10-85 slope of upper half of main channel in feet per mile.	72.7	
SLOPERATIO	Ratio of main channel slope to basin slope as defined in SIR 2006-5112	0.0858	dimensionless
CENTROIDX	Basin centroid horizontal (x) location in state plane coordinates	596420.7	
CENTROIDY	Basin centroid vertical (y) location in state plane units	4649704.9	
CONTOUR	Total length of all elevation contours in drainage area in miles	104.54	
CSL10_85	Change in elevation divided by length between points 10 and 85 percent of distance along main channel to basin divide - main channel method not known	34.5	feet per mi
DRNAREA	Area that drains to a point on a stream	26	square miles
EL1200	Percentage of basin at or above 1200 ft elevation	0	percent

Parameter Code	Parameter Description	Value	Unit
FOREST	Percentage of area covered by forest	68.8	percent
JULAVPRE	Mean July Precipitation	4.26	inches
JUNAVPRE	Mean June Precipitation	3.94	inches
JUNMAXTMP	Maximum June Temperature, in degrees F	78.9	degrees F
LAGFACTOR	Lag Factor as defined in SIR 2006-5112	0.53	dimensionless
LC11DEV	Percentage of developed (urban) land from NLCD 2011 classes 21-24	11.9	percent
LC11IMP	Average percentage of impervious area determined from NLCD 2011 impervious dataset	2.83	percent
LENGTH	Length along the main channel from the measuring location extended to the basin divide	15.3	miles
MAR	Mean annual runoff for the period of record in inches	18.9	inches
MAYAVPRE	Mean May Precipitation	4.46	inches
MXSNO	50th percentile of seasonal maximum snow depth from Northeast Regional Climate Center atlas by Cember and Wilks, 1993	15.9	inches
OUTLETX	Basin outlet horizontal (x) location in state plane coordinates	590375	
OUTLETY	Basin outlet vertical (y) location in state plane coordinates	4651655	
PRECIP	Mean Annual Precipitation	39.2	inches
PRJUNAUG00	Basin average mean precip for June to August from PRISM 1971-2000	12.2	inches
SSURGOA	Percentage of area of Hydrologic Soil Type A from SSURGO	9.84	percent
SSURGOB	Percentage of area of Hydrologic Soil Type B from SSURGO	46.7	percent
STORAGE	Percentage of area of storage (lakes ponds reservoirs wetlands)	2.93	percent

Bankfull Statistics Parameters [Bankfull Region 3 SIR2009 5144]

Parameter Code	Parameter Name	Value	Units	Min Limit	Max Limit
DRNAREA	Drainage Area	26	square miles	0.42	329

Bankfull Statistics Flow Report [Bankfull Region 3 SIR2009 5144]

PIl: Prediction Interval-Lower, Plu: Prediction Interval-Upper, SEp: Standard Error of Prediction, SE: Standard Error (other -- see report)

Statistic	Value	Unit	PIl	Plu
Bankfull Area	205	ft^2	92.1	456
Bankfull Depth	3.29	ft	1.55	6.97
Bankfull Streamflow	766	ft^3/s	185	3170
Bankfull Width	62.1	ft	28.9	134

Bankfull Statistics Citations

Mulvihill, C.I., Baldigo, B.P., Miller, S.J. , and DeKoskie, Douglas,2009, Bankfull Discharge and Channel Characteristics of Streams in New York State: U.S. Geological Survey Scientific Investigations Report 2009-5144, 51 p. (http://pubs.usgs.gov/sir/2009/5144/)

Appendix B – Figures

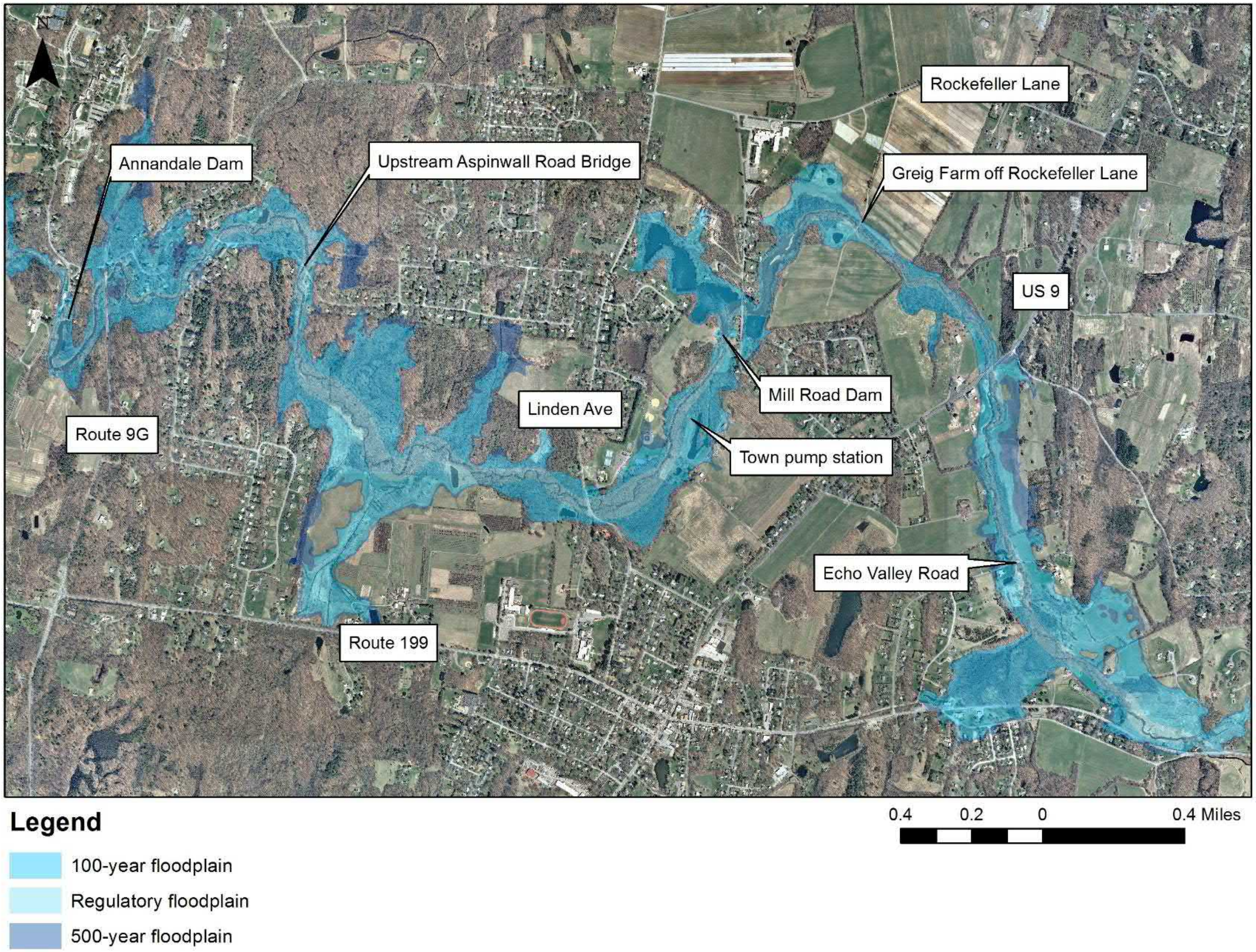


Figure 1. FEMA floodplain from Annandale Dam upstream to NY State Highway 199. Flow direction is from east to west. Data sources: Natural Flood Hazard Layer, Dutchess County, FEMA; Digital orthoimagery, Town of Red Hook, NYS Digital Orthoimagery Program.

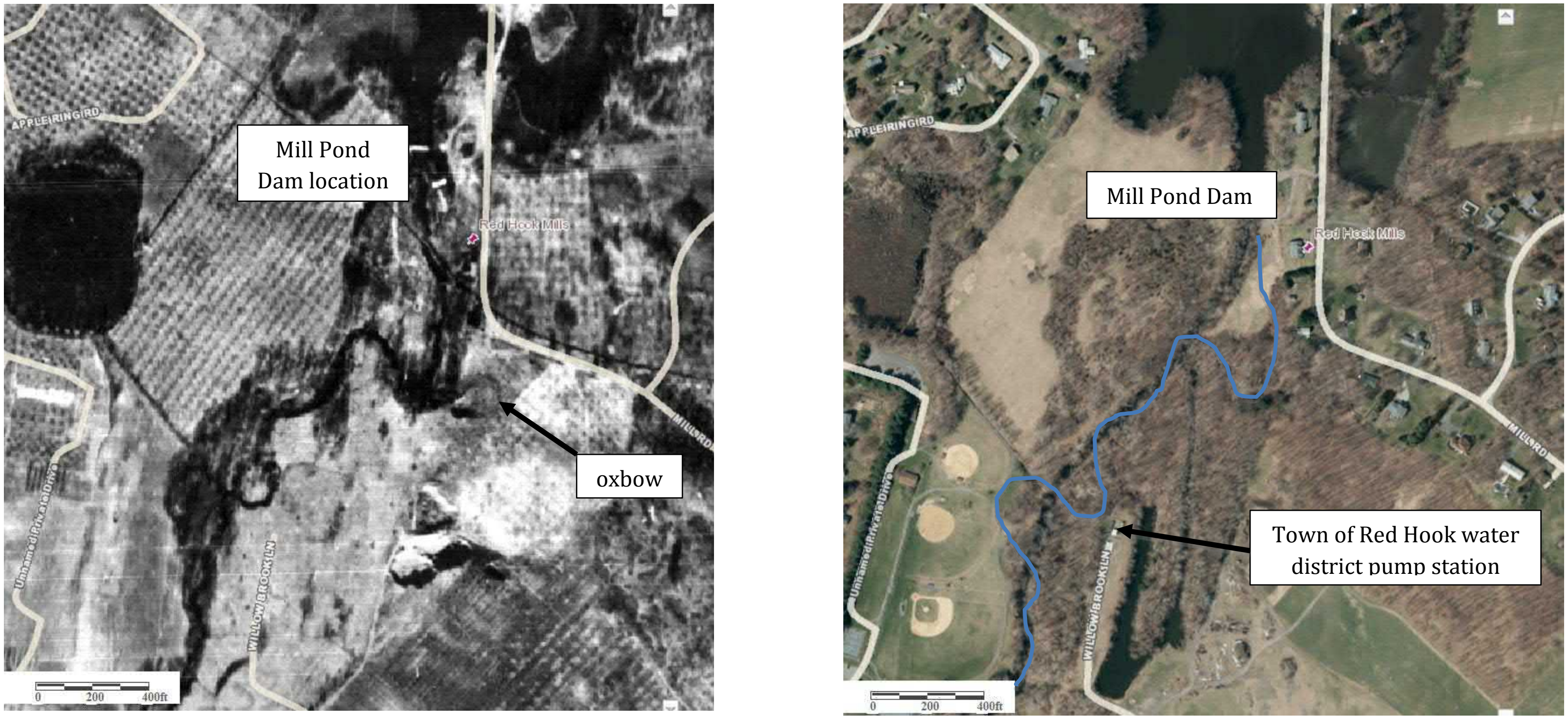
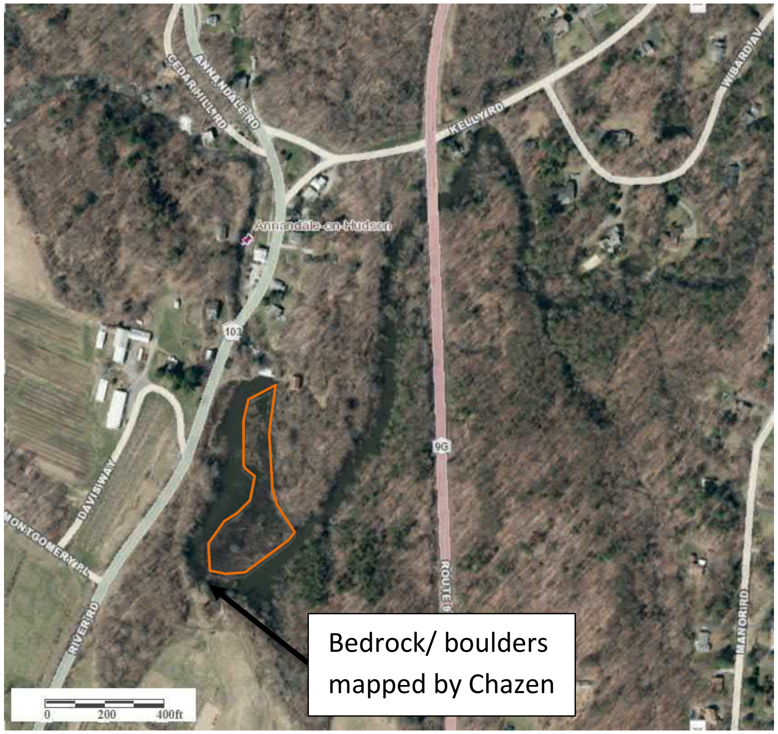


Figure 2. Aerial photographs of the Saw Kill immediately below Mill Pond Dam showing how this reach was channelized. The photograph on the left is from 1936, and the photo on the right is from 2014. A trace of the 1936 channel is shown overlain onto the 2014 image. Data source: http://geoaccess.co.dutchess.ny.us/aerialaccess/. Accessed September 24, 2017.



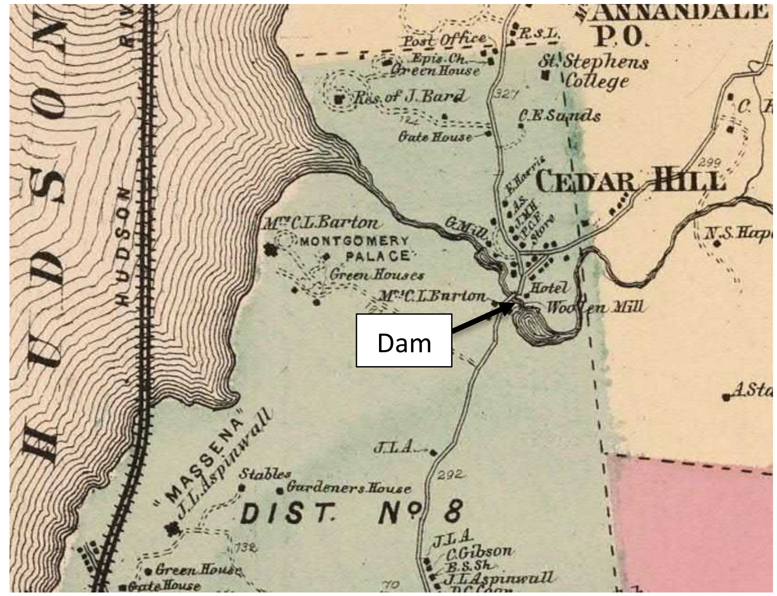


Figure 3. On left, 2014 aerial photograph with colonized impounded sediment outlined in orange (http://geoaccess.co.dutchess.ny.us/aerialaccess/, accessed September 24, 2017). On right, 1867 map showing mill (labelled "Woolen Mill") and open water impoundment behind the dam (Beers, Frederick W., 1867. Town of Red Hook, Dutchess County, NY, 1:31,680. Accessed on September 24, 2017 via the David Rumsey Historical Map Collection, https://www.davidrumsey.com).

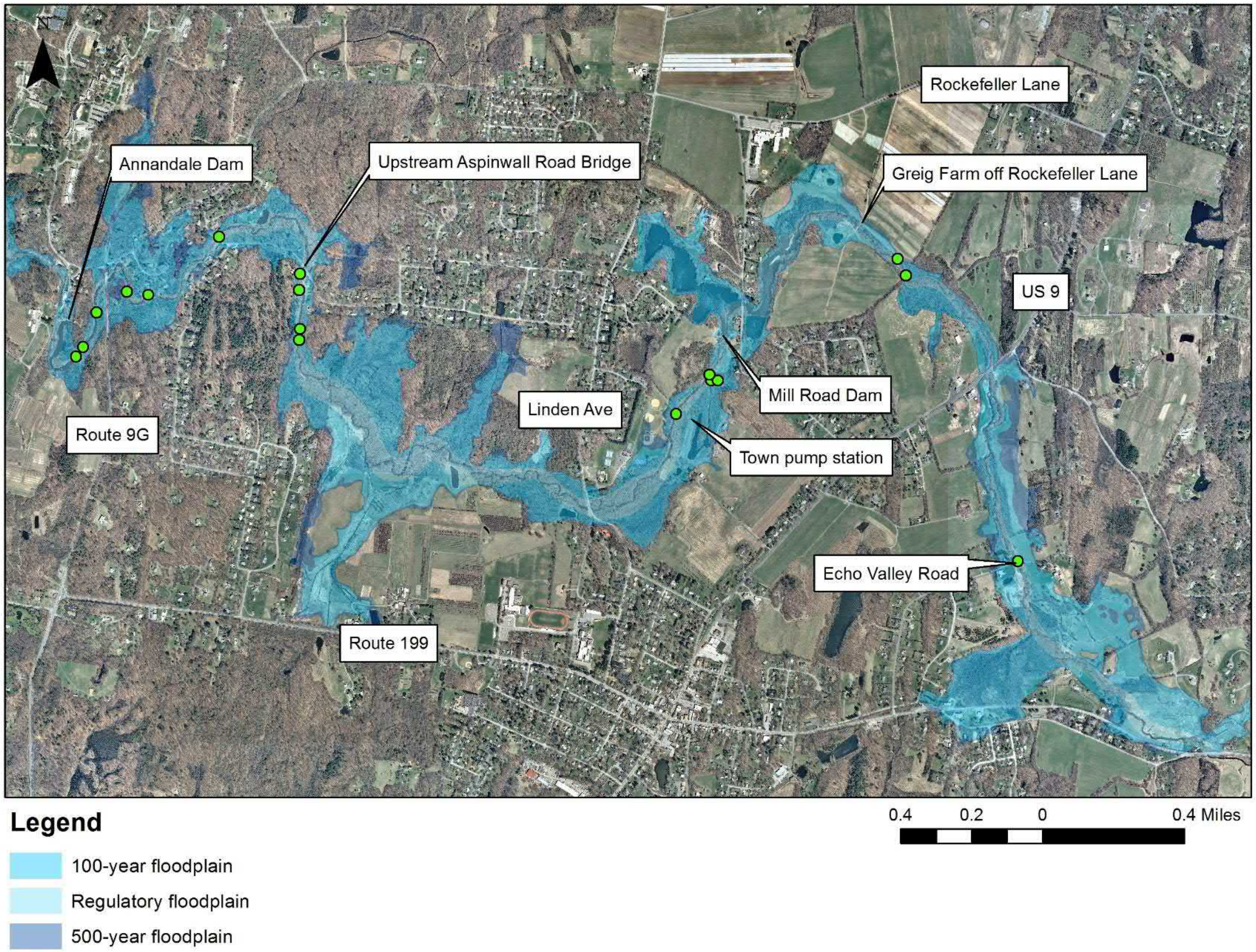


Figure 4. Map showing field assessment locations as green points. Not shown is Battenfeld Road in the upper watershed. Data sources: Natural Flood Hazard Layer, Dutchess County, FEMA; Digital orthoimagery, Town of Red Hook, NYS Digital Orthoimagery Program.

Figure 5. Map of bathymetric and depth of refusal survey data collected at Annandale Dam (orange points) and other inspection points (green). Locations of observed bedrock seams are shown as red lines. The furthest upstream bedrock seam shown on the map corresponds with the upstream extent of the impounded water surface during low-flow conditions.

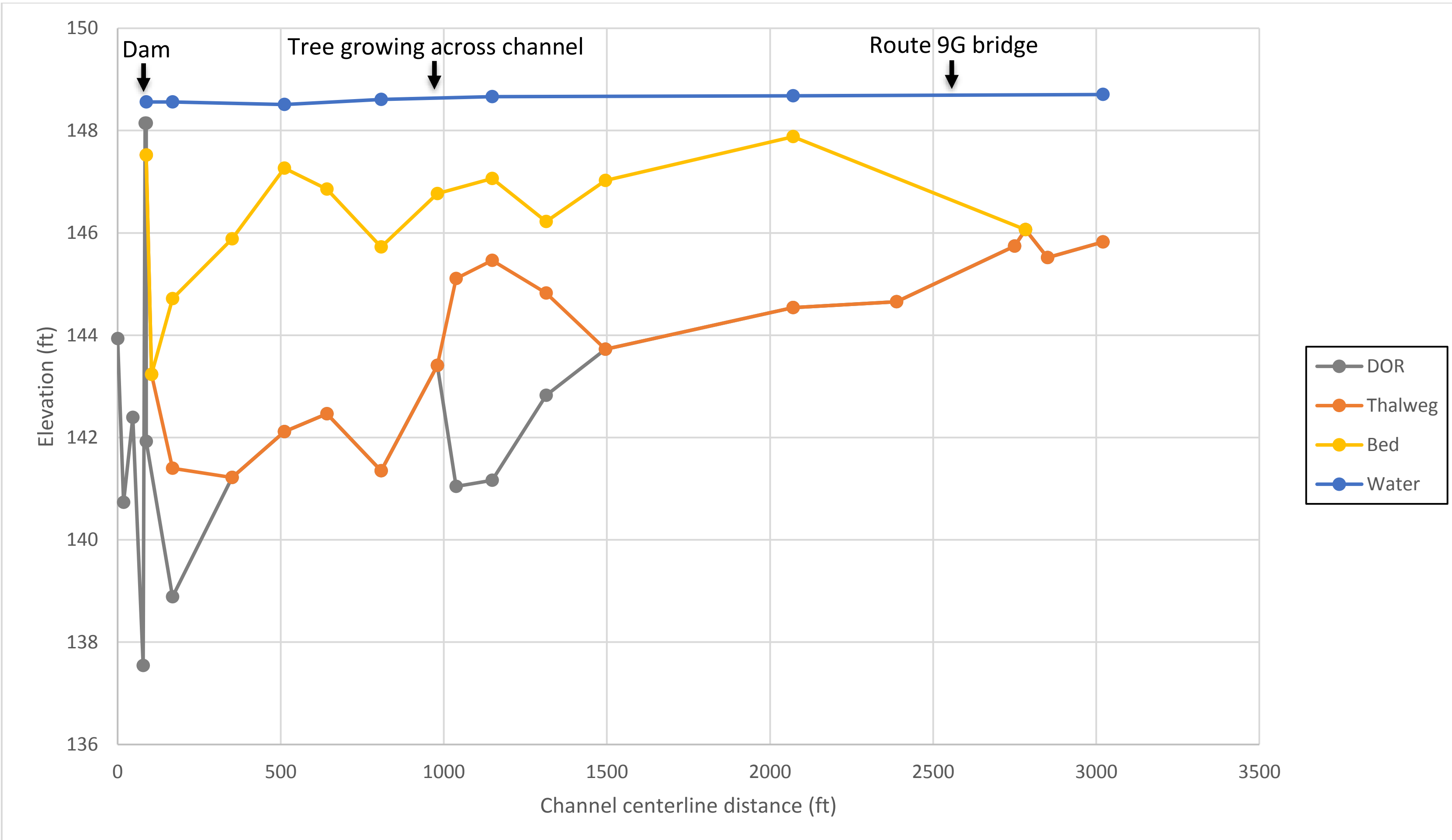


Figure 6. Longitudinal profile through the impoundment showing depth of refusal (DOR), the bed surface along the thalweg of the channel through the impoundment (thalweg), the bed surface along the right side (inside of meander bend) of the channel through the impoundment (bed), and the water surface (water). Elevation is relative to the NAD 83 datum.

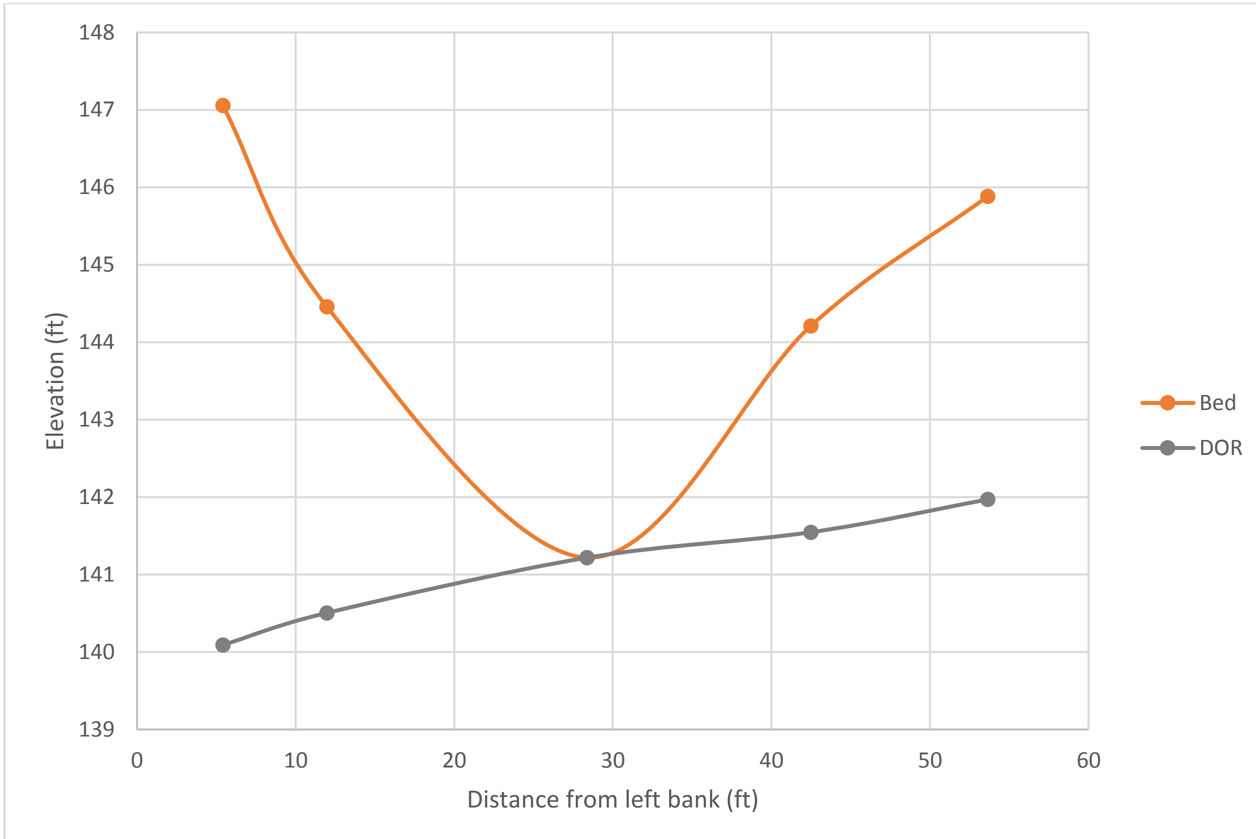


Figure 7. Cross section through the impoundment taken approximately 265 feet upstream of the dam showing depth of refusal (DOR) and the bed surface (bed). Elevation is relative to the NAD 83 datum.

Figure 8. Relic channel on left bank floodplain downstream of Mill Road Dam. The arrow indicates flow direction along the approximate location of the preserved thalweg.

Figure 9. High-flow channel feeding pond adjacent to Town wellfield. The arrow indicates flow direction into the high-flow channel from the main channel.

Figure 10. On left, the relic dam along Battenfeld Road. On right, the channel looking downstream toward an undersized culvert beneath a private driveway.

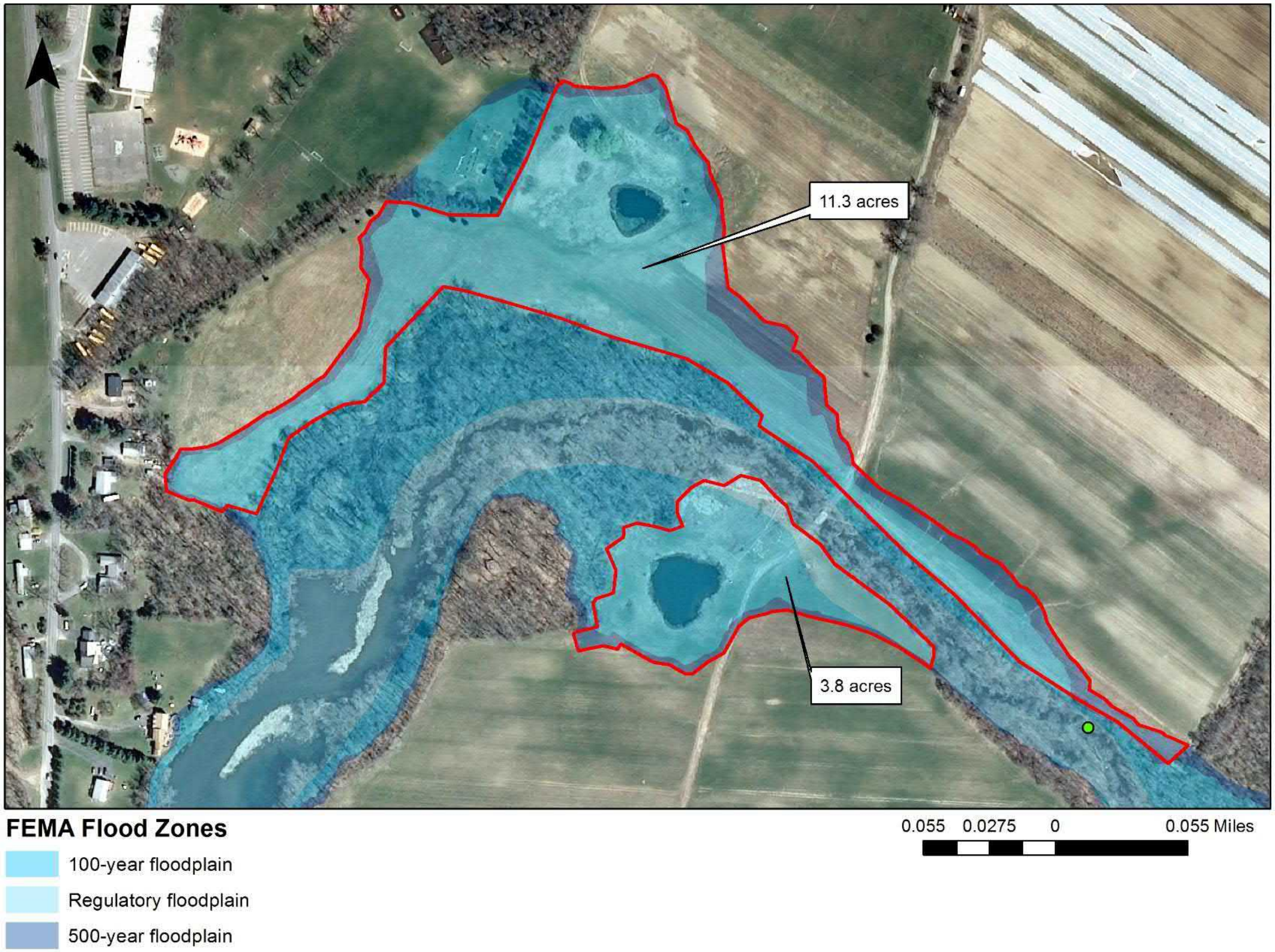


Figure 11. Potential areas of riparian buffer expansion at Greig Farm off of Rockefeller Lane. Flow direction is from east to west.

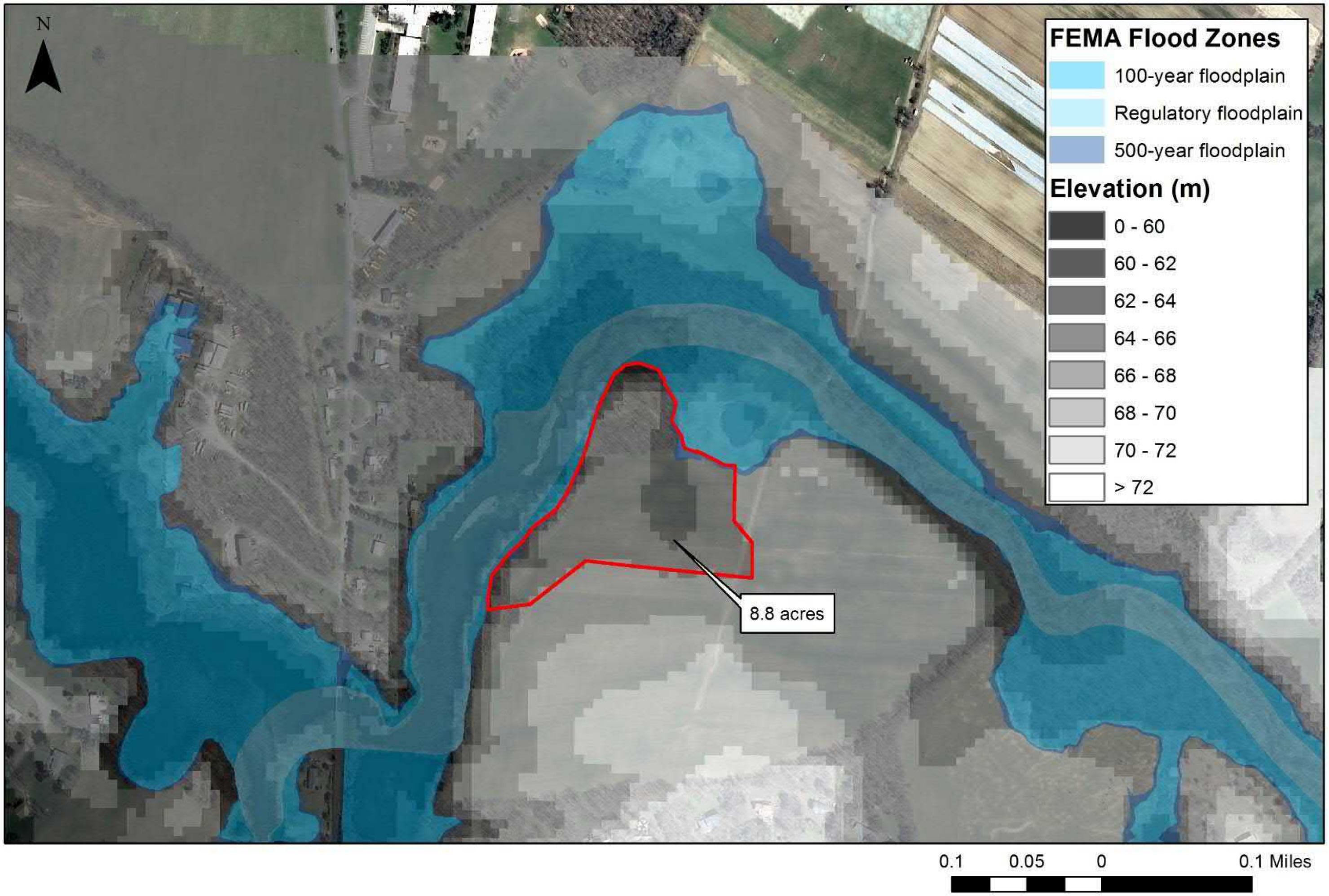


Figure 12. Potential flood storage area at Greig Farm off of Rockefeller Lane. Flow direction is from east to west.

Appendix C – Field Data Collection Sheets

Channel Reconnaissance Form

Date	9/1/17
Stream/Drainage	Saw Kill
Stream Reach ID	Upstream of the upstream-most Aspinwall Bridge. XS1 is approx. 1150 ft upstream of the bridge, and XS2 is approx. 100 ft upstream of the bridge
Field Team	CC, NN

Station ______ **to** ______

General Channel Conditions

Sediment Particle Size Estimate		
	D_{50}	D_{max}
Banks	Silt/clay, rock	
Bars	N/A	
Bed	Silt, silt and boulders/cobbles	

Channel Shape (check)

☐ Rectangular

☐ Shallow Rectangular

☐ Irregular

X Trapezoidal

☐ Parabolic

☐ Other ________________

Bar Types (circle): Alternate lateral | Point / transverse | None (circled) | Mid-channel | Point / mid | Point / alternate

Fluvial Geomorphic Conditions

<table>
<tr><td>Vertical Stability
degradation/aggradation</td><td colspan="5">No signs of significant aggradation or degradation. Very low gradient channel with accumulation of silt on bed upstream of a small rock dam built by property owner (dam is approx. 350 ft upstream of the bridge).</td></tr>
<tr><td>Lateral stability *deposition, erosion*</td><td colspan="5">Channel stable. Mature trees growing along banks are stable. No change in plan form since the 1930s.</td></tr>
<tr><td>Channel evolution (Schumm)
Stage/description:</td><td colspan="5"></td></tr>
<tr><td>Erosion (excessive/site specific)</td><td colspan="5">No signs of excessive erosion</td></tr>
<tr><td rowspan="2">Dominant bank erosion types
(circle any that apply)</td><td>*Fluvial*</td><td>Undercut / cantilever</td><td>Selective erosion of noncohesive laters</td><td>Dry flow</td><td>Seepage</td></tr>
<tr><td>*Gravitational*</td><td>Rotational</td><td>Planar</td><td>Wedge</td><td></td></tr>
<tr><td>Bank composition</td><td colspan="3">*Notes (shape/character)*: Fine-grained with rock at the base in places</td><td colspan="2">*Consolidation / Aggregation*:</td></tr>
<tr><td>Terrace/Valley</td><td colspan="3">*Valley form* – Relatively narrow valley rising gently on either side of a narrow floodplain</td><td colspan="2">*Condition* –</td></tr>
<tr><td>Altered state (human) - dams, bridges, canoe landings, parks, etc.</td><td colspan="5">Very low gradient reach. Evidence of some bank scour immediately upstream of Aspinwall Bridge where eddies form at high flows when water backs up behind the bridge. Upstream, a small rock dam built by property owner causes backwater at low flow, and silt has accumulated on the bed.</td></tr>
<tr><td>Bankfull/Channel forming flow indication</td><td colspan="5">Lower, vertical section of bank indicates height of OHW.</td></tr>
</table>

Sediment Impacts

Riffle sediment type	N/A	Pool sediment type	N/A
Sorting / Imbrication			

Bars / depositional features

Sediment type/size	Silt or silt and boulders/cobbles. No bedforms.
Mid, alternate, braided	
Bar Vegetation (type, age)	
Floodplain soils	Silt loam. Root bound
Overbank deposition	None visible

Riparian Vegetation and Floodplain

Root coverage of banks (%)	25
Width of veg. riparian corridor*	
Canopy coverage (%)	100

** Verify with orthoquad data*

Canopy structure: (check one)

none = anthro / maintained (lawn, field, pasture)	
low = single canopy layer	
medium = at least two canopy layers	X
high = multiple canopy layers	

Primary veg forms present: (%)

grasses/forbs	In areas where floodplain is lower
woody species	100% elsewhere
bare/other	Manicured lawns where floodplain developed
Exotic/invasive species	

Woody species present	% of total tree community
Ash, cottonwood, basswood, maple, oak, walnut, elm, sycamore, ironwood saplings	

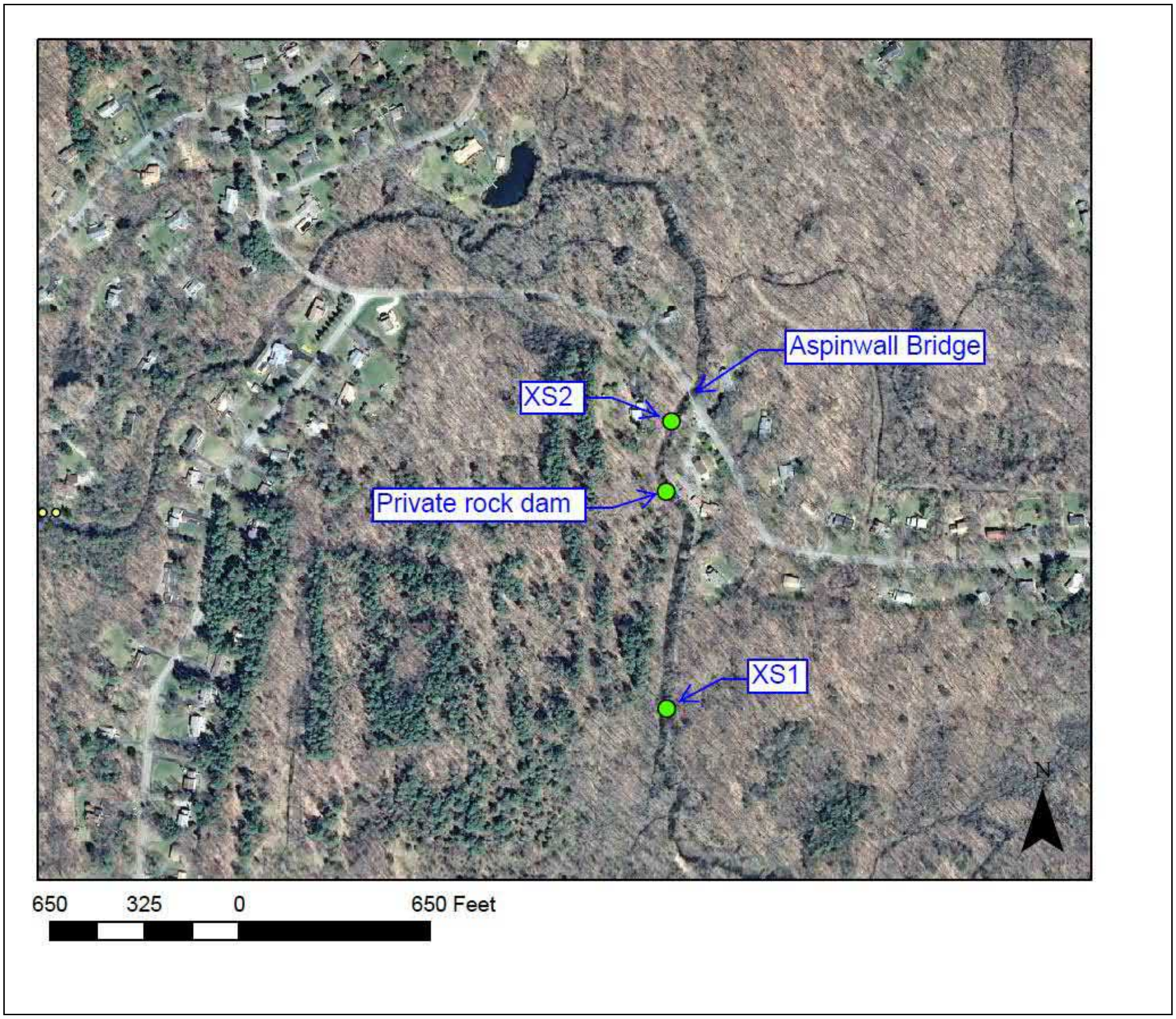
Tree Stand Age (if applicable)

Station	*Species*	*Age*	*Notes / Location within XS*

Habitat

LWD density (pieces / 100 ft)	Low	General Habitat notes: Low habitat complexity. Some substrate variability. Some scour and deposition around large wood. Good canopy cover but no overhanging vegetation and few undercut banks.
Residual pool	0.5 to 1.0 ft around large wood	
Undercut bank	Few	
Riffle / Other	None	

Representative cross-section sketch		
Bankfull width XS1 = 33 ft Bankfull width XS2 = 29 ft Bankfull depth XS1 = 3 ft Bankfull depth XS2 = 4 ft	Floodplain width = Channel Class =	Water depth (at survey) XS1 = 2 ft Water depth XS2 = 2.5 ft Water width (at survey) =


Aspinwall Bridge
XS2
Private rock dam
XS1
N
650
325
0
650 Feet

Cross section XS1 looking downstream

Cross section XS2 looking downstream

Channel Reconnaissance Form

Date	9/1/17			
Stream/Drainage	Saw Kill			
Stream Reach ID	From Mill Road Dam downstream approximately 1350 ft. Includes cross section XS3 located 600 ft downstream of dam.			
Field Team	CC, NN	**Station**		**to**

General Channel Conditions

Sediment Particle Size Estimate		
	D_{50}	D_{max}
Banks	Sand and gravel	
Bars	N/A	
Bed	Coarse sand, small gravel to cobbles	

Channel Shape (check)

☐ Rectangular

☐ Shallow Rectangular

☐ Irregular

X Trapezoidal

☐ Parabolic

☐ Other _______________

Bar Types (circle): Alternate lateral | Point / transverse | None (circled)

Mid-channel | Point / mid | Point / alternate

<table>
<tr><th colspan="6">Fluvial Geomorphic Conditions</th></tr>
<tr><td>Vertical Stability degradation/aggradation</td><td colspan="5">Stable, very low gradient</td></tr>
<tr><td>Lateral stability deposition, erosion</td><td colspan="5">Stable, artificially straightened. Some undercutting of left bank.</td></tr>
<tr><td>Channel evolution (Schumm) Stage/description:</td><td colspan="5"></td></tr>
<tr><td>Erosion (excessive/site specific)</td><td colspan="5">No excessive erosion</td></tr>
<tr><td rowspan="2">Dominant bank erosion types (circle any that apply)</td><td>Fluvial</td><td>Undercut / cantilever (circled)</td><td>Selective erosion of noncohesive laters</td><td>Dry flow</td><td>Seepage</td></tr>
<tr><td>Gravitational</td><td>Rotational</td><td>Planar</td><td>Wedge</td><td></td></tr>
<tr><td>Bank composition</td><td colspan="3">Notes (shape/character):</td><td colspan="2">Consolidation / Aggregation:</td></tr>
<tr><td>Terrace/Valley</td><td colspan="3">Valley form – Terrace on the right bank with no floodplain present. Wider floodplain on the left bank.</td><td colspan="2">Condition –</td></tr>
<tr><td>Altered state (human) - dams, bridges, canoe landings, parks, etc.</td><td colspan="5">Artificially dredged and straightened channel. Relict meanders on left bank floodplain.</td></tr>
<tr><td>Bankfull/Channel forming flow indication</td><td colspan="5">OHW is approx 1.5 ft above current water level as indicated by lower, vertical section of bank</td></tr>
</table>

Sediment Impacts

Riffle sediment type	N/A	Pool sediment type	Sand and gravel/cobble bed with silt throughout. No well-defined pools.
Sorting / Imbrication			

Bars / depositional features

Sediment type/size	No bedforms present until approx. 1350 ft downstream of Mill Road Dam where a riffle is present.
Mid, alternate, braided	
Bar Vegetation (type, age)	
Floodplain soils	
Overbank deposition	Channel dredged and overly deep. No evidence of overbank flooding.

Riparian Vegetation and Floodplain

		Canopy structure: (check one)	
Root coverage of banks (%)	50	none = anthro / maintained (lawn, field, pasture)	
Width of veg. riparian corridor*		low = single canopy layer	
Canopy coverage (%)	100	medium = at least two canopy layers	
** Verify with orthoquad data*		high = multiple canopy layers	X

Primary veg forms present: (%)		Woody species present	% of total tree community
grasses/forbs		Ash, cottonwood, basswood, maple, oak, walnut, elm	
woody species	100		
bare/other			
Exotic/invasive species	Buckthorn		

Tree Stand Age (if applicable)

Station	*Species*	*Age*	*Notes / Location within XS*

Habitat

LWD density (pieces / 100 ft)	Low	General habitat notes: Very limited morphological and flow complexity. Some undercut banks.
Residual pool	None	
Undercut bank	Some	
Riffle / Other	None	

Representative cross-section sketch

Bankfull width XS3 = 48 ft Bankfull width Riffle = 34 ft Bankfull depth XS3 = 5 ft Bankfull depth Riffle = 3 ft	Floodplain width = Channel Class =	Water depth (at survey) XS3 = 1 ft Water depth (at survey) Riffle = 0.5 ft Water width (at survey) =

Cross section XS3 looking downstream

Riffle approx. 1350 ft downstream of Mill Road Dam looking downstream

Channel Reconnaissance Form

Date	9/1/17			
Stream/Drainage	Saw Kill			
Stream Reach ID	Grieg Farm, from farm road access crossing upstream 1,050 ft. Includes cross section XS4 approx. 780 ft upstream of crossing.			
Field Team	CC, NN	**Station**		**to**

General Channel Conditions

Sediment Particle Size Estimate		
	D_{50}	D_{max}
Banks	Silt to sand and cobbles	
Bars	N/A	
Bed	Sand to cobbles	

Channel Shape (check)

☐ Rectangular

☐ Shallow Rectangular

☐ Irregular

X Trapezoidal

☐ Parabolic

☐ Other _______________

Bar Types (circle): Alternate lateral — Point / transverse — (None) [circled]

Mid-channel — Point / mid — Point / alternate

Fluvial Geomorphic Conditions

Vertical Stability *degradation/aggradation*	No evidence of vertical instability				
Lateral stability *deposition, erosion*	Some lateral movement: Erosion of bluffs (source of cobbles), split flow, small vegetated islands within channel, no regular bar deposits				
Channel evolution (Schumm) Stage/description:					
Erosion (excessive/site specific)	No excessive erosion				
Dominant bank erosion types (circle any that apply)	*Fluvial*	Undercut / cantilever	Selective erosion of noncohesive layers	Dry flow	Seepage
	Gravitational	Rotational	Planar	Wedge	
Bank composition	*Notes (shape/character)*: Lower bank vertical with more gently sloping upper bank. Generally fine-grained bank material with some gravel.		*Consolidation / Aggregation*:		
Terrace/Valley	*Valley form* – Cross section XS4 measured just downstream of pinch point between floodplain terraces. Left bank 75-ft wide active floodplain with overflow channels. No floodplain on right. Top of terrace approx. 6 ft above bankfull.		*Condition* –		
Altered state (human) - dams, bridges, canoe landings, parks, etc.	Hillslopes farmed on either side of channel. Narrow riparian corridor.				
Bankfull/Channel forming flow indication	OHW indicated by lower, vertical section of bank.				

Sediment Impacts			
Riffle sediment type	Gravel/ cobble - D50 32-45mm	Pool sediment type	Sand and gravel
Sorting / Imbrication			

Bars / depositional features	
Sediment type/size	N/A
Mid, alternate, braided	Small mid-channel islands where present are vegetated. Formation appears to be associated with large woody debris.
Bar Vegetation (type, age)	Woody, herbaceous
Floodplain soils	Silt loam
Overbank deposition	Evidence of overbank flooding when low floodplain present. Flood debris and some fine sand deposition.

Riparian Vegetation and Floodplain

		Canopy structure : (check one)	
Root coverage of banks (%)	75	none = anthro / maintained (lawn, field, pasture)	
Width of veg. riparian corridor*		low = single canopy layer	
Canopy coverage (%)	70	medium = at least two canopy layers	
** Verify with orthoquad data*		high = multiple canopy layers	X

Primary veg forms present: (%)		Woody Species present	% of total tree community
grasses/forbs		Ash, cottonwood, basswood, maple, oak, walnut, elm	
woody species	X		
bare/other			
Exotic/invasive species	Purple loosestrife		

Tree Stand Age (if applicable)

Station	*Species*	*Age*	*Notes / Location within XS*

Habitat

LWD density (pieces / 100 ft)	Low/med	General Habitat notes: Riffle-pool sequences present with longitudinal substrate variability and active sediment transport. Some undercut banks.
Residual pool	Some with 1-2 ft residual depth	
Undercut bank	Some	
Riffle / Other	Riffle/pool sequences	

Representative cross-section (XS4)

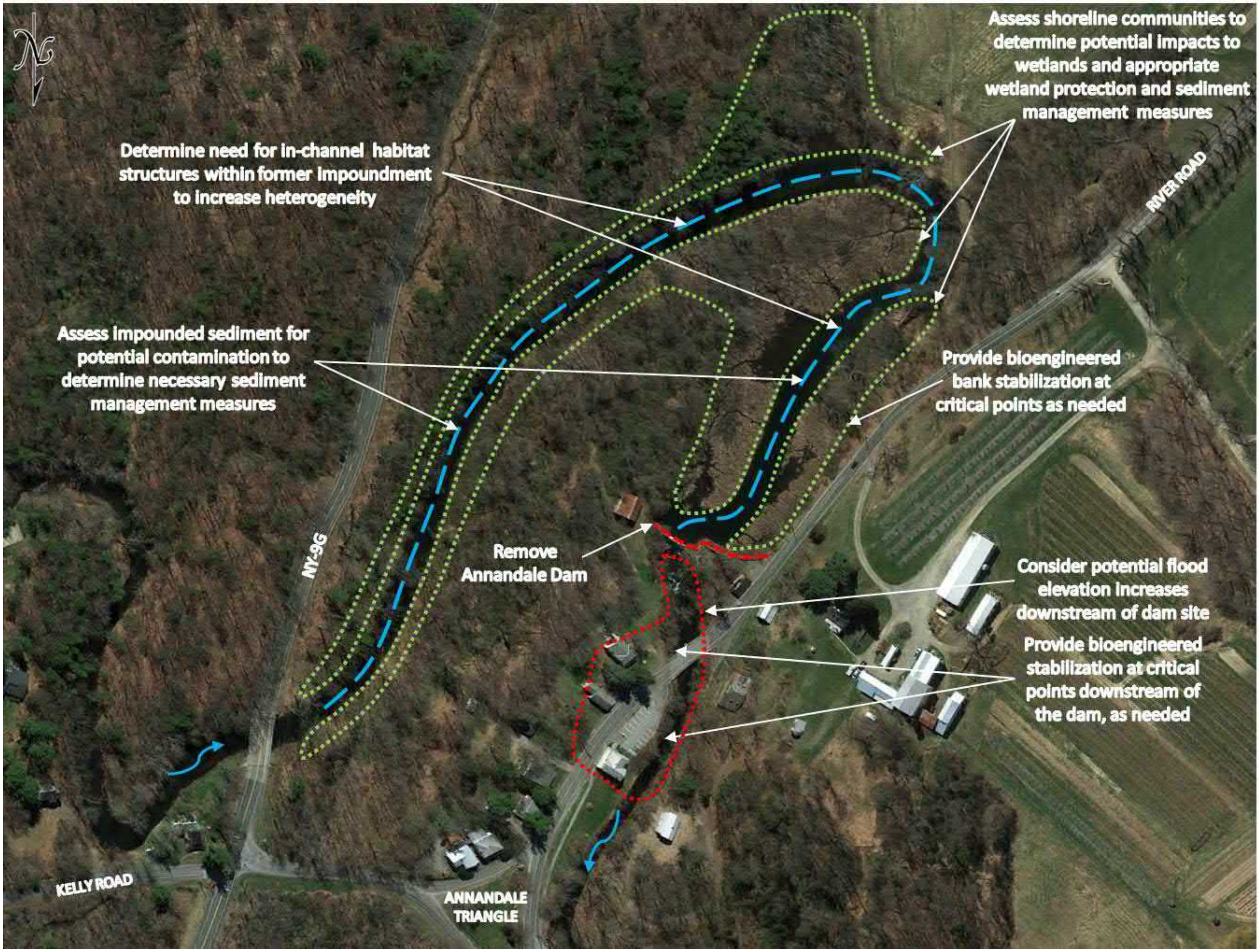
Bankfull width = 35 ft Bankfull depth = 3.5 ft	Floodplain width = Channel Class =	Water depth (at survey) = 1 ft Water width (at survey) =

Cross section XS4 looking downstream

Appendix F

Conceptual Recommendation Figures

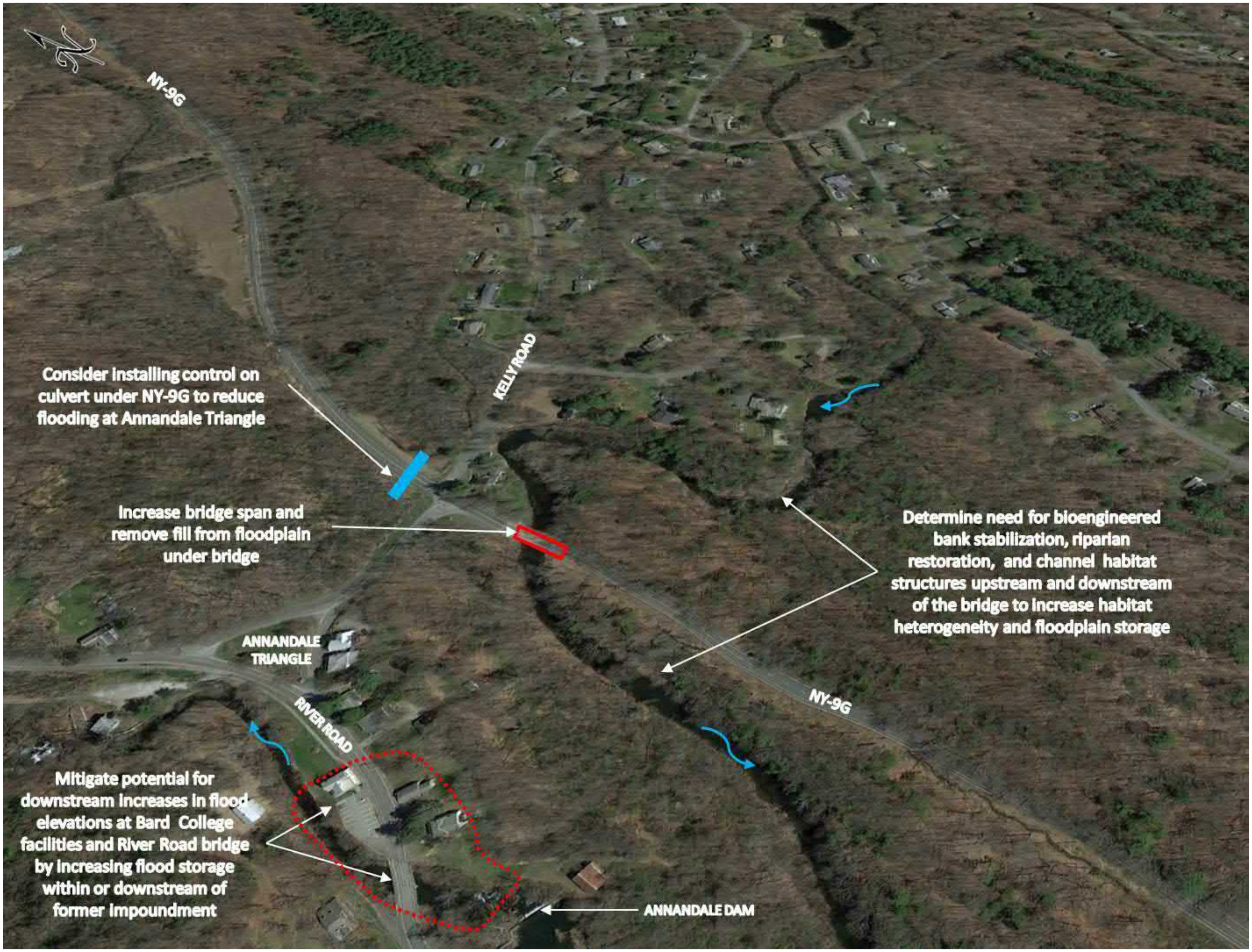
Recommendation #1 – Annandale Dam
Remove Dam
River Road, Red Hook, New York



Recommendation #2 – NY-9G Bridge

Replace and Upgrade Bridge

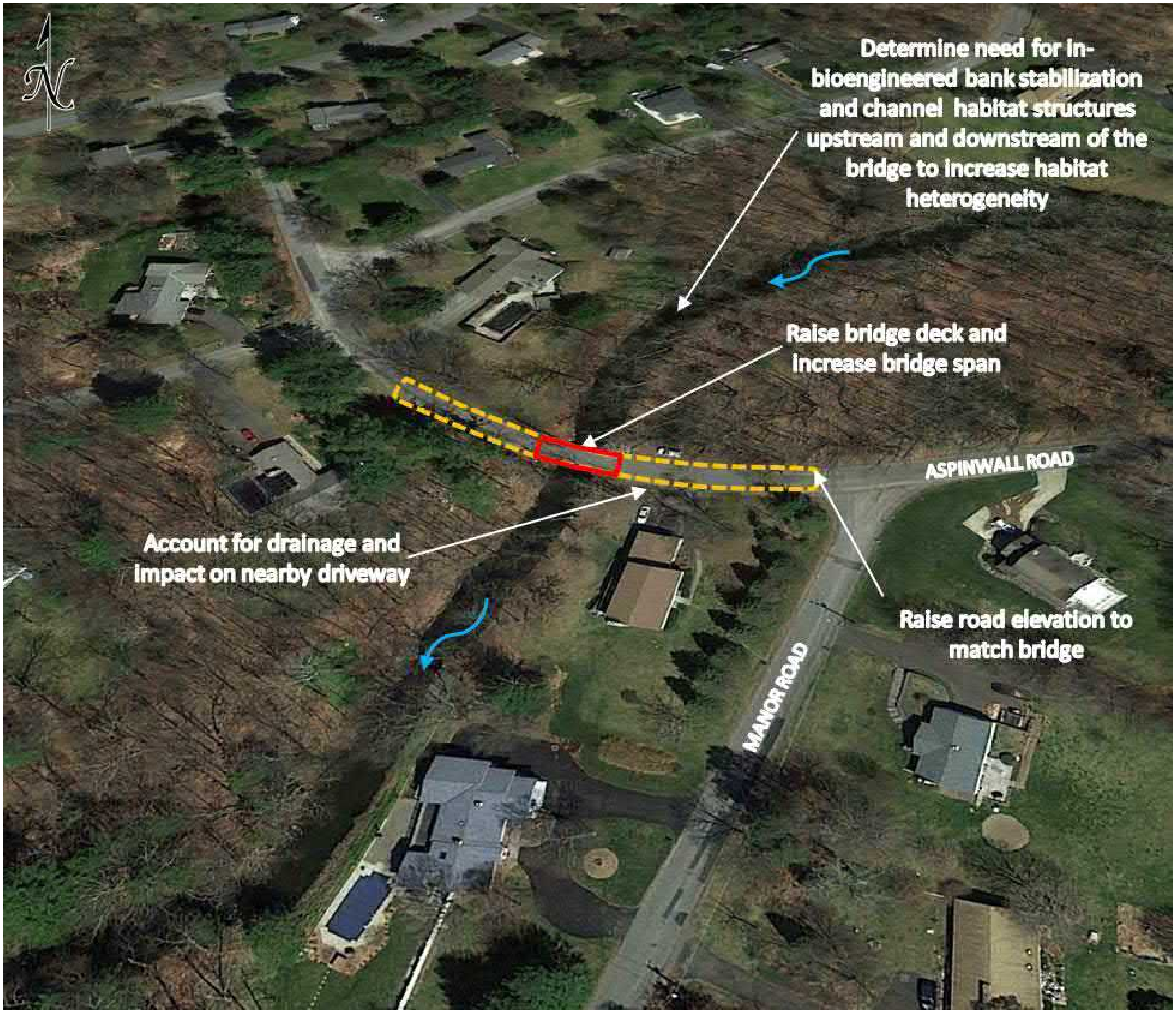
NY-9G at Kelly Road, Red Hook, New York



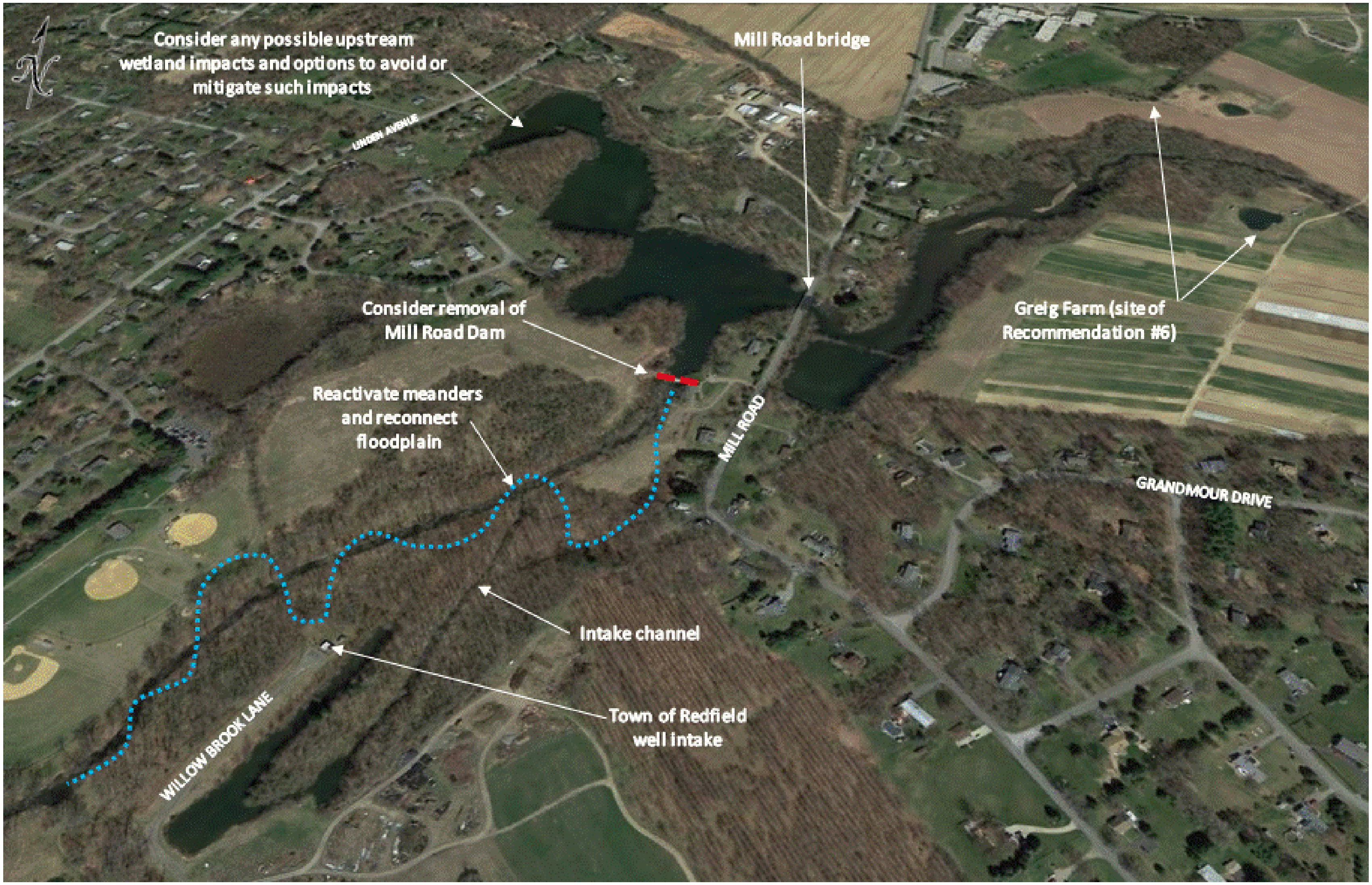
Recommendation #3 – Aspinwall Road Bridge

Replace and Upgrade Bridge and Elevate Road Approaches

Aspinwall Road (downstream crossing), Red Hook, New York



Recommendations #4 and #5– Mill Road Dam
Remove Dam and Reactivate Stream Meanders Downstream of Dam
Mill Road, Red Hook, New York



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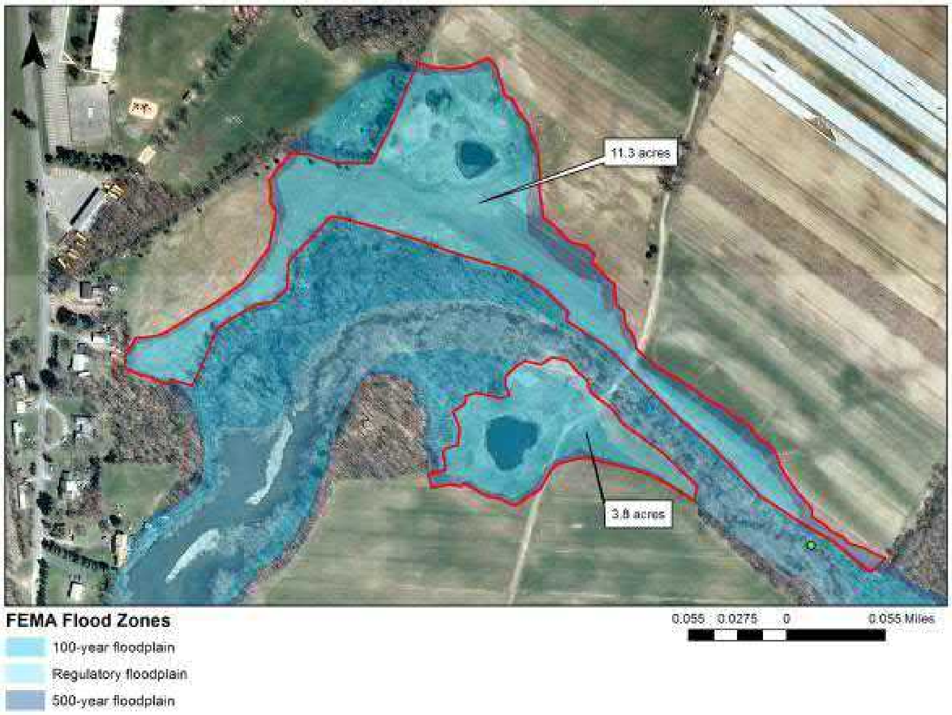
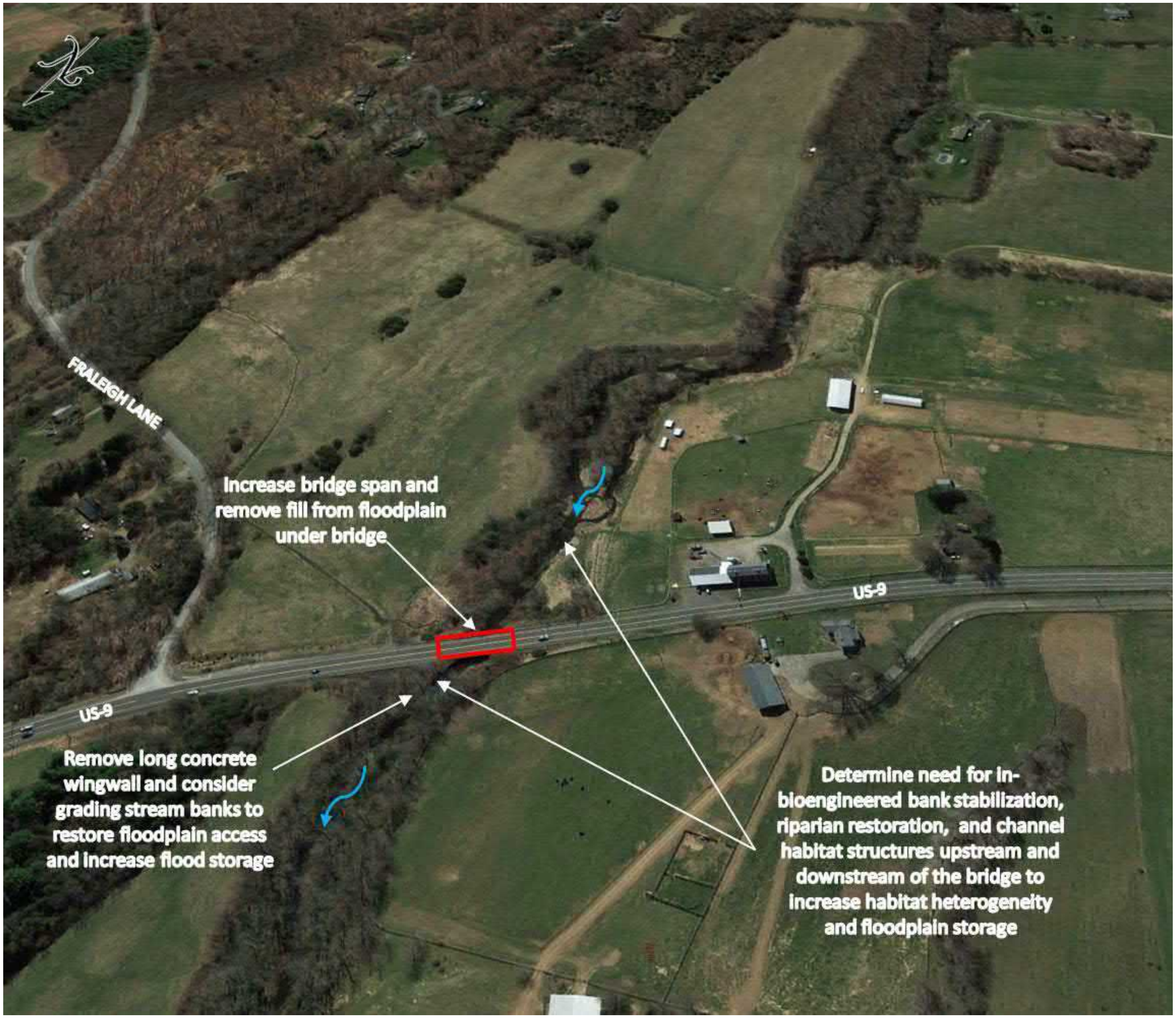
Recommendation #6 – Greig Farm

Expand Riparian Buffer and Increase Flood Storage

Greig Farm, Red Hook, New York



Recommendation #7 – US-9 Bridge
Replace and Upgrade Bridge
US-9, Red Hook, New York



Recommendations #8 and #9 – Echo Valley Road Bridge

Replace and Realign Bridge and Reconstruct Stable Upstream Channel Bed and Banks

Echo Valley Road, Red Hook, New York

Recommendation #10 – Battenfeld Road
Remove Failed Dam
Battenfeld Road, Milan, New York

Appendix G

Site-Specific Recommendations Matrix

Recommendations Matrix

	Recommendation	Flood Risk Benefits					Ecological and Geomorphic Benefits			Other Factors			
		Change in Flood Depth at Structure	Changes in flood depths upstream	Potential for Interruption of Public, Commercial, or Emergency Services	Flood Risk at Residential or Other Buildings	Risk of Catastrophic Failure	Impact on Natural Flow Regime	Impact on Fluvial Erosion Risk	Impact on Aquatic and/or Terrestrial Connectivity	Structure Condition	Sediment Management/Disposal	Anticipated Impacts to Public Water Supplies	Stakeholder Support
1	Remove Annandale Dam	Flood depths are reduced	Flood depths are reduced	Reduced flood WSEs at NY-9G bridge reduce risk to bridge structure, which is classified by NYSDOT as an Urban Major Collector, reducing risk of traffic and emergency service interruptions. River Road Bridge, would no longer be at risk for failure due to catastrophic failure of Annandale Dam. The bridge currently overtops during the existing 100-year and future 50- and 100-year floods, but would experience increased flood elevations during these storms if the Annandale Dam is removed and additional flood storage is not provided.	Flood elevations at the residence immediately upstream of the NY-9G bridge and at residences along West Bard Road would reduced for all floods analyzed, with the geratest decrease of approx. 1 foot occuring for the existing 10-year flood. Schafer House and 21 Cedar Lane would no longer be at risk due to catastrophic failure of Annandale Dam, but the Bard College facility at 1259 River Road (the former Annandale Hotel) would experience increased flood depths during the existing 100-year and future 50- and 100-year floods	Full removal of structure will eliminate the potential for a dam failure to impact the River Road Bridge, Schafer House, 21 Cedar Lane, and Bard Water Intake	Removal of the dam will eliminate the artificial impoundment behind the dam, restoring natural streamflows.	Increased velocities through area of stream currently impounded may initially lead to erosion of sediments within the impoundment or erosion downstream of the dam; erosion potential will be limited by bedrock seams at the dam site and upstream end of the impoundment. The system is expected to stabilize after an initial period of adjustment but bioengineered bank stabilization and adaptive management may be needed.	Dam removal will facilitate both upstream and downstream aquatic organism passage (AOP), including passage for American Eels. The dam is not a significant barrier to terrestrial connectivity	The dam is currently rated as "Unsound - Fair" by NYSDEC and significant repair work would be required to repair the dam to the degree required by state law. Structure is rated a Hazard Class "B" (Intermediate Hazard) dam, meaning that it presents a risk to homes, infrastructure, and the environment, but loss of human life is not expected if the structure were to fail. Under this classification, it is considered to have inadequate spillway capacity.	Although sediment sampling has been conducted in the impoundment previously, additional sediment sampling is required to fully characterize impounded sediment, including the possible presence of contaminants detected in Lower Annandale Dam. A sediment management plan will be required.	Modeling indicates the Bard surface water intake will not experience changes in flood levels as a result of the dam removal. However, the sediment management plan should include consideration of this water supply.	The dam owner is willing to consider dam removal, but is also considering other potential uses for the structure (i.e. hydropower). No major opposition to dam removal has been mentioned anecdotally or at stakeholder meetings. NYSDEC supports dam removal, but are concerned about possible wetland impacts
2	Replace and Upgrade NY-9G Bridge	Flood depths are reduced	Flood depths are reduced	Reduced flood WSEs at NY-9G bridge reduce risk to bridge structure, which is classified by NYSDOT as an Urban Major Collector, reducing risk of traffic and emergency service interruptions. River Road Bridge The bridge currently overtops during the existing 100-year and future 50- and 100-year floods, but would experience increased flood elevations during these storms if the bridge span is not increased and additional flood storage is not provided.	Flood elevations at the residence immediately upstream of the NY-9G bridge and at residences along West Bard Road would reduced for all floods analyzed, with the geratest decrease of approx. 0.6 feet occuring for the existing 10-year flood. The Bard College facility at 1259 River Road (the former Annandale Hotel) would experience increased flood depths during the existing 100-year and future 50- and	As long as the structure remains, there is a risk of catastrophic failure, but reducing flood elevations at the structure reduces the probability of failure.	Bridge replacement will reduce a known flow constriction	Increased bridge span will reduce risk of erosion near bridge; erosion potential will be limited by bedrock seams at the dam site and upstream end of the impoundment.	The bridge is currently not considered a significant barrier to aquatic passage. Enlarging the bridge span will improve terrestrial connectivity under the bridge, allowing terrestrial wildlife to avoid crossing the road.	Bridge constructed in 1931 and rehabilitated in 1986.	N.A.	Modeling indicates the Bard surface water intake will not experience changes in flood levels as a result of the bridge replacement.	Contact NYSDOT and determine current NYSDOT replacement or repair schedule for this state-owned bridge . Upstream landowners should be included in community meetings; one residence immediately upstream of bridge may be directly impacted by increased bridge span.
3	Replace and Upgrade Downstream Aspinwall Road Bridge and Elevate Road Approaches	Flood depths are reduced; elevating the bridge reduces the frequency of overtopping	Small reductions in upstream flood levels. Would need to replace/elevate the upstream Aspinwall Bridge to reduce the frequency with which the upper Aspinwall bridge overtops.	Reduced flood WSEs and increased bridge elevation at bridge reduce risk to traffic and emergency service interruptions. Reduced flood WSEs at upstream Aspinwall Road bridge only slightly reduce risk to transportation infrastructure. Would need to replace/elevate the upstream bridge to reduce frequency of overtopping.	Small (<1 ft) flood reduction expected in neighborhood upstream of bridge. No significant increase expected in flood levels downstream of the bridge	As long as the structure remains, there is a risk of catastrophic failure, but reducing flood elevations at the structure reduces the probability of failure.	Bridge replacement will reduce a known flow constriction	All banks currently exhibit erosion with vertical banks up to 3' high, per 2016 NYSDOT bridge inspection. Bridge replacement and restoration of the natural flow regime will reduce erosion potential.	The bridge is currently not considered a significant barrier to aquatic passage. Enlarging the bridge span will improve terrestrial connectivity under the bridge, allowing terrestrial wildlife to avoid crossing the road.	Town frequently makes repairs to bridge after rain events Deficiencies noted in 2016 NYSDOT bridge inspection but no action items recommended	N.A.	No impacts to public water supplies are anticipated	The community will likely support the replacement of the bridge, due to known flooding issues. Raising the bridge deck and road approaches may impact nearby properties, requiring coordination with the property owners.
4	Consider Removal or Modification of Mill Road Dam	Significant flood depth reductions possible.	Significant flood depth reductions possible.	The Mill Road bridge does not overtop during the 100-year flood but is under pressure flow for 50- and 100-year events. Flood level reductions will reduce risk of damage resulting from pressure flow or debris. The Linden Avenue bridge, which is classified by NYSDOT as an Urban Major Collector, would no longer be at risk for failure due to catastrophic failure of the Mill Road Dam	In 2011 the abutments of the dam overtopped causing severe erosion on private property adjacent to and downstream of the dam. The risk of flooding and erosion of private properties by overtopping of the dam abutments or Mill Road will be reduced by dam removal.	Full removal of structure will eliminate the potential for a dam failure to impact the Town of Red Hook well intake, Linden Avenue, recreational fields, and a private footbridge.	Removal of the dam will reduce or eliminate the artificial impoundment behind the dam, restoring natural streamflows.	Risk of erosion by floodwaters overtopping the dam abutments (as occurred in 2011) will be eliminated. Increased velocities through area of stream currently impounded may initially lead to erosion within the impoundment, but bioengineered bank stabilization and adaptive management may be needed. Erosion impacts may extend upstream and downstream unless natural grade controls exist under sediment. System will eventually stabilize after an initial period of adjustment but adaptive management may be needed/geomorphic impacts should be investigated more closely if dam removal is considered. Recommendations #5 and #6 may help limit fluvial erosion risk.	The dam appears to have been built at a natural waterfall; removal would facilitate downstream passage but would probably provide upstream passage benefits only for American eels. The dam is not a significant barrier to terrestrial connectivity	Unknown - No inspection data available Structure is rated a Hazard Class "B" (Intermediate Hazard) dam, meaning that it presents a risk to homes, infrastructure, and the environment, but loss of human life is not expected if the structure were to fail.	Sediment sampling required to characterize impounded sediment. Any contaminated sediment may require off-site disposal in the event of dam removal, which could significantly impact project cost. A sediment management plan will be required.	The dam is located within the Town of Red Hook Wellfield; lowering of the dam impoundment upon dam removal may impact groundwater elevations within the wellfield; further investigation is needed to determine if the water supply would be impacted. Water quality impacts of dam removal should be investigated further.	Currently, the dam and its impoundment support a number of recreational uses and the pond is an important aesthetic and cultural feature for the property owners around the pond and local residents. The dam owner does not currently actively use or maintain the structure, but is considering potential alternative uses. It is generally believed that property owners along the impoundment shoreline would prefer the impoundment to remain in place.
5	Expand Riparian Buffer and Increase Flood Storage at Greig Farm	Flood depths expected to decrease	Flood depths may remain constant or increase slightly in undeveloped area	Reduction of flood risk at Mill Road bridge possible due to increased flood storage, reducing risk of traffic and emergency service interruptions	Reduction of flood risk at residential and other structures around Mill Road Dam impoundment and along Mill Road possible due to increased flood storage and reduced risk of overtopping at Mill Road	N.A.	Increased riparian buffer will help restore natural flow regime	Fluvial erosion risk expected to decrease	No significant barrier to passage known at the site	N.A.	Sediment excavated to create flood storage area may require sampling.	Increased riparian buffer can potentially filter runoff and improve downstream water quality in Town of Red Hook wellfield	A portion of this property is already under a conservation easement. Discuss this option further with affected landowners to determine feasibility.
6	Reactivate Stream Meanders Downstream of Mill Road Dam	Flood depths may remain constant or increase slightly in undeveloped area	Flood depths may remain constant or increase slightly in undeveloped area	Indirect reduction of flood risk at downstream bridge possible due to increased flood storage, reducing risk of traffic and emergency service interruptions	Indirect reduction of flood risk at downstream possible due to increased flood storage	N.A.	Reactivation of meanders and reconnection to floodplain will help restore natural flow regime	Fluvial erosion risk expected to decrease	No significant barrier to passage known at the site	N.A.	N.A.	Meanders will retain water in Town of Red Hook wellfield; restoration of floodplain will benefit natural water filtering processes and reduce erosion that may impact downstream water quality	Discuss this option further with affected landowners to determine feasibility.
7	Replace US-9 bridge	Flood depths are reduced	Flood depths are reduced	Potential flood elevation reductions at both US-9 and Echo Valley Road bridge reduce risk of traffic and emergency service interruptions	Flood depth reduction expected at Sawkill Farm, upstream of US-9 bridge	As long as the structure remains, there is a risk of catastrophic failure, but reducing flood elevations at the structure reduces the probability of failure.	Bridge replacement will eliminate a known flow constriction	Bridge replacement and restoration of the natural flow regime will reduce erosion potential; because the upstream crossing is not aligned with the stream channel, increasing the span would also reduce geomorphic risk to the structure	The bridge is currently not considered a significant barrier to aquatic passage. Enlarging the bridge span will improve terrestrial connectivity under the bridge, allowing terrestrial wildlife to avoid crossing the road.	Bridge constructed in 1928. 2017 NYSDOT hydraulic vulnerability analysis recommends that bridge be replaced as it is "past [its] useful lifespan".	N.A.	No impacts to public water supplies are anticipated	Contact NYSDOT and determine current NYSDOT replacement or repair schedule. No community opposition is anticipated; bridge replacement would have little direct impact on the public except during flood conditions
8	Replace and Realign Echo Valley Road Bridge	Flood depths expected to decrease	Small reduction in upstream flood levels possible.	Reduced flood WSEs at Echo Valley Road bridge reduce risk of traffic and emergency service interruptions.	Flood elevation reduction possible at car wash and other structures on Orlich Road, but unlikely due to small size of Echo Valley Road bridge.	As long as the structure remains, there is a risk of catastrophic failure, but reducing flood elevations at the structure reduces the probability of failure.	Bridge replacement will reduce a known flow constriction	Bridge replacement and restoration of the natural flow regime will reduce erosion potential; because the upstream crossing is not aligned with the stream channel, increasing the span would also reduce geomorphic risk to the structure	The bridge is currently not considered a significant barrier to aquatic passage. Enlarging the bridge span will improve terrestrial connectivity under the bridge, allowing terrestrial wildlife to avoid crossing the road.	Bridge constructed in 1924 Bridge considered Functionally Obsolete by NYSDOT as of 2018, possibly due to poor alignment, narrow lanes, or frequency of overtopping during floods.	N.A.	No impacts to public water supplies are anticipated	Upstream landowner anecdotally reported to oppose bridge realignment. Downstream landowner has reported erosion to his property as a result of recent bridge repairs. Discuss this option further with affected landowners to determine feasibility.
9	Reconstruct Channel Upstream of Echo Valley Road bridge with Stable Bed and Banks	Flood depths expected to decrease or remain constant	Flood depths may remain constant or increase slightly in undeveloped area	Indirect reduction of flood risk at downstream bridges possible due to reduced stream channel migration and debris movement, reducing risk of traffic and emergency service interruptions	No significant impacts are anticipated	N.A.	Streambed and bank stabilization can maintain or enhance natural flow regime	Fluvial erosion risk expected to decrease	No significant barrier to passage known at the site	N.A.	Sediment removed from channel may be considered for use in stabilizing banks.	Stabilized stream banks can reduce erosion and potentially filter pollutants from runoff to improve downstream water quality.	Discuss this option further with affected landowners to determine feasibility.
10	Remove Failed Dam on Battenfeld Road	Flood depths expected to decrease	Small reduction in upstream flood levels possible.	Removal of dam would reduce risk of backwater flooding on Battenfeld Road during large storms	Minor benefits to nearby residences possible through flood level reductions.	Dam has failed; removal of remaining structure and pieces of dam would reduce risk of further failure and associateddamage to downstream driveway and culverts by debris and sediment flow	Removal of the dam will reduce or eliminate the artificial impoundment behind the dam, restoring natural streamflows.	No significant changes to fluvial erosion risk expected; removal of sediment behind dam will reduce risk of downstream culvert(s) being plugged by sediment transported downstream	No significant barrier to passage known at the site; stream possibly intermittent	Structure has failed	Minor amount of excavation and grading required to remove sediment behind dam	No impacts to public water supplies are anticipated	No opposition to dam removal anticipated. Discuss this option further with affected landowners to determine feasibility.

Appendix H

Cost Range of Recommended Actions

Cost Range of Recommended Actions

	Recommendation	Cost Range < $100,000	 $100,000 - $500,000	 $500,000 - $1 million	 $1 million - $5 million	 >$5 million
1	Remove Annandale Dam			X	X	
2	Replace and upgrade NY-9G bridge					X
3	Replace downstream Aspinwall Bridge and elevate road approaches				X	
4	Consider removal of Mill Road Dam				X	
5	Expand riparian buffer at Greig Farm	X				
5	Increase flood storage at Greig Farm				X	
6	Reactivate stream meanders downstream of Mill Road Dam			X	X	
7	Replace and upgrade US-9 bridge					X
8	Replace and realign Echo Valley Road bridge			X		
9	Reconstruction stable channel upstream of Echo Valley Road bridge	X	X			
10	Remove failed dam at Battenfeld Road	X				

Notes: Costs shown in the table above reflect potential planning-level project cost ranges for each of the major site-specific recommendations. The numbered notes below correspond to the numbered recommendations in the table.

1 Costs anticipated to vary between $500,000 and $1 million. Previous cost estimates by Chazen range from $390,000 to $730,000. This is a reasonable range based on experience with similar projects; however, this study found significantly more impounded sediment than the previous Chazen study. Estimated the additional earthwork volume to be approximately 2,000 CY and have added this to the costs. Also increased the contingency to 30% given the stage of the project and uncertainty in sediment management and bank stabilization. If additional offsite disposal of impounded sediment is required, then costs will be higher.

2 Bridge replacement - large bridge, long span, major fill removal, possibly realignment

3 Bridge replacement - large bridge, long span, road raising, full repaving, private property conflicts

4 Coasts anticipated to be in excess of $1 million based on experience with similar scale dam removal projects. Hydraulic modeling, flood mitigation downstream, structure removal (large), possible sediment management and off-site disposal, wetland conservaiton/mitigation.

5 Riparian Buffer: Costs anticipated to vary between $7,000 and $29,000. Range reflects differences in planting density and need for invasives control. Includes maintenance during warranty period. Excludes cost of land purchase or easement where needed.
Increase Flod Storage: Costs anticipated to vary between $1.3 and $3.7 million. Assumes an average of 2.5 feet of excavation over approximately 9 acres. Range reflects varying options for reuse of material. Excludes cost of land purchase or easement where needed.

6 Costs anticipated to vary between $840,000 and $1.3 million. Approximately 2,000 ft of stream channel. Range reflects varying level of effort in terms of earthwork and extent of on-site reuse of material.

7 Bridge replacement - large bridge, long span, major fill removal

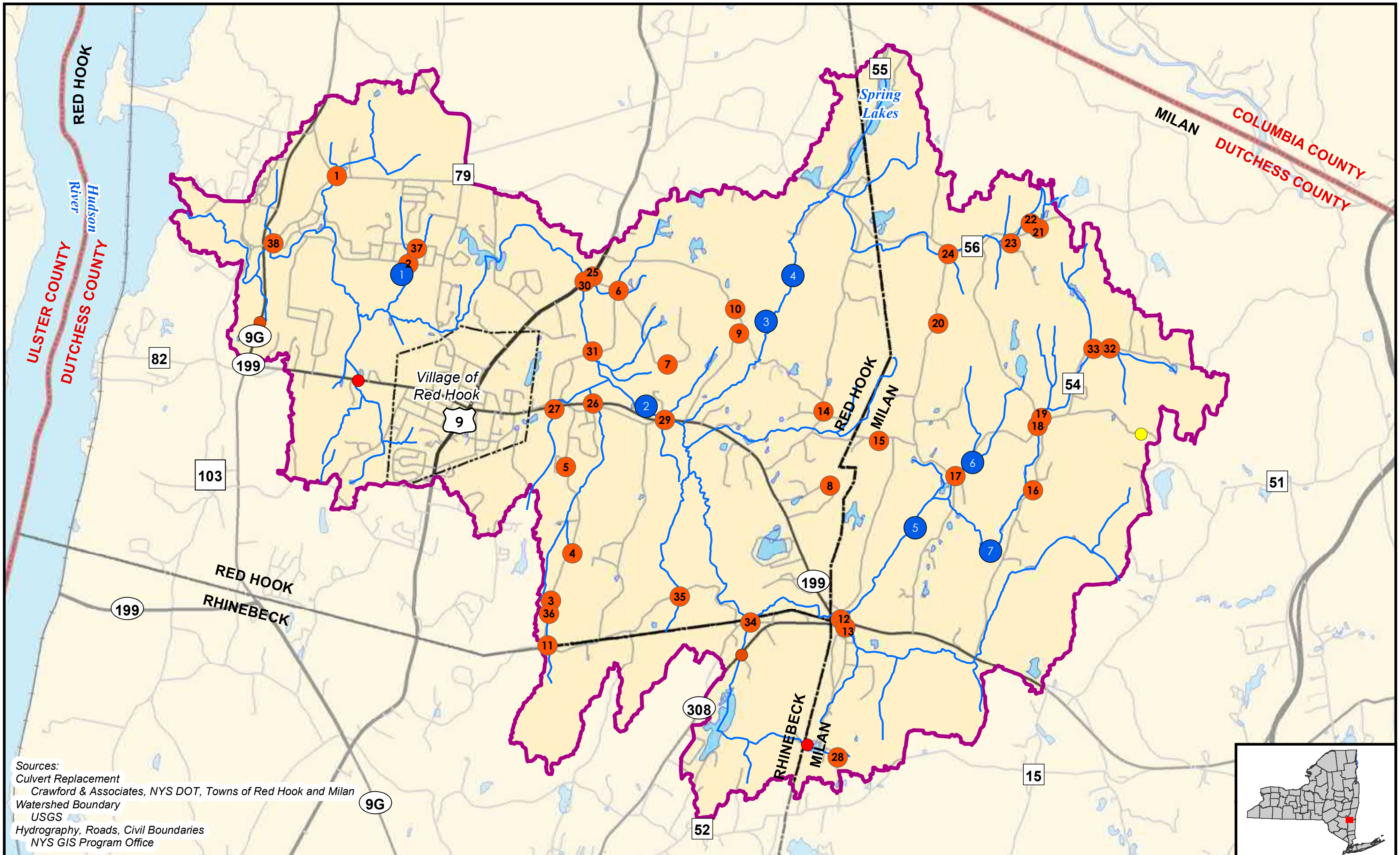
8 Bridge replacement - relatively small bridge, could realign only within right-of-way

9 Costs anticipated to vary between $50,000 and $300,000. Approximately 100 to 150 ft of stream channel. Range reflects varying length and level of effort in terms of bank and bed reconstruction.

10 Costs anticipated to vary between $15,000 and $50,000. Demolition and concrete disposal, minor grading and seeding. Assumes minimal design input. Permitting will likely involve wetland delineation and state permitting.

Appendix I

Targeted Recommendations Maps



Potential Floodplain Reconnection and Stream Crossing Replacement

Saw Kill Watershed

FUSS & O'NEILL

PROJ. No. 20161136.A1N

DATE: FEBRUARY 2018

N W E S

0 0.5 1 Miles

- ID Potential Floodplain Reconnection
- ID Potential Culvert Replacements
- Streams
- Surface Water
- Watershed Boundary

Other Assessed Culverts

- 1 Year, Moderate barrier
- 2 Year, Moderate barrier
- 5 Year, Moderate barrier

Path: K:\P2016\1136\A1N\MXD\SawKill_ParcelBased_Recommendations_FP_Culverts.mxd

Culvert Upgrades and Replacements

Label	Road	Municipality	Stream	Passability	Future (2050) Capacity	Source
1	Kelly Rd & Whalesback Rd	Red Hook	Trib to Saw Kill	Moderate	<1-year flowrate	Crawford and Associates, 2017 Walter et al. 2015
2	Aspinwall Rd	Red Hook	Trib to Saw Kill	Significant	1-year flowrate	Crawford and Associates, 2017 Walter et al. 2015
3	Norton Rd	Red Hook	Trib to Saw Kill	Moderate	<1-yearflood	Crawford and Associates, 2017 Walter et al. 2015
4	Norton Rd	Red Hook	Trib to Saw Kill	Moderate	2-year flowrate	Crawford and Associates, 2017 Walter et al. 2015
5	Norton Rd	Red Hook	Trib to Saw Kill	Significant	10-year flowrate	Crawford and Associates, 2017 Walter et al. 2015
6	Fraleigh Ln	Red Hook	Trib to Saw Kill	Significant	N/A	Crawford and Associates, 2017 Walter et al. 2015
7	Fraleigh Ln	Red Hook	Trib to Saw Kill	Significant	<1-year flowrate	Crawford and Associates, 2017 Walter et al. 2015
8	W. Willets Rd	Red Hook	Trib to Saw Kill	Significant	<1-year flowrate	Crawford and Associates, 2017 Walter et al. 2015
9	Crestwood Rd	Red Hook	Trib to Lakes Kill	Moderate	<1-year flowrate	Crawford and Associates, 2017 Walter et al. 2015
10	Feller Newmark Rd	Red Hook	Trib to Lakes Kill	Moderate	2-year flowrate	Crawford and Associates, 2017 Walter et al. 2015
11	Oriole Mills Rd	Red Hook	Trib to Saw Kill	Significant	<1-year flowrate	Walter et al. 2015
12	Rock City Rd	Milan	Saw Kill	Moderate	Insufficient	Town of Milan, Past flooding location
13	Old Mill Rd	Milan	Trib to Saw Kill	Moderate	Insufficient	Town of Milan, Past flooding location
14	Hapeman Hill Rd	Red Hook	Trib to Saw Kill	Significant	N/A	Walter et al. 2015
15	Saint Paul	Milan	Trib to Saw Kill	Significant	N/A	Walter et al. 2015
16	Milan Hill Rd	Milan	Trib to Saw Kill	Significant	N/A	Walter et al. 2015
17	Battenfeld Rd & Shookville Rd	Milan	Trib to Saw Kill	Moderate	Insufficient	Fuss & O'Neill site visit
18	Battenfeld Rd & Beckerhill Rd	Milan	Trib to Saw Kill	Moderate	Insufficient	Town of Milan, Past flooding location
19	Battenfeld Rd & Beckerhill Rd	Milan	Trib to Saw Kill	Moderate	Insufficient	Town of Milan, Past flooding location
20	Shookville Rd	Milan	Trib to Saw Kill	Significant	N/A	Walter et al. 2015
21	Turkey Hill Rd	Milan	Trib to Lakes Kill	Significant	<1-year flowrate	Walter et al. 2015
22	Fulton Homestead	Milan	Trib to Lakes Kill	Significant	N/A	Walter et al. 2015
23	Mitchell Rd	Milan	Trib to Lakes Kill	Significant	N/A	Walter et al. 2015
24	Shookville Rd & Turkey Hill Rd	Milan	Trib to Lakes Kill	Moderate	Insufficient	Town of Milan, Past flooding location
25	Fraleigh Ln	Red Hook	Trib to Saw Kill	Significant	N/A	Walter et al. 2015
26	Rt 199 Car Wash	Red Hook	Trib to Saw Kill	Moderate	Insufficient	Walter et al. 2015; Past flooding location
27	Rt 199 Car Wash	Red Hook	Trib to Saw Kill	Minor	Insufficient	Past flooding location
28	Brooklyn Heights	Red Hook	Trib to Saw Kill	Significant	<1-year flowrate	Walter et al. 2015
29	Rt 199	Red Hook	Saw Kill	Moderate	Insufficient	NYS DOT, 2017a
30	US 9	Red Hook	Saw Kill	N/A	Insufficient	NYS DOT, 2017b
31	Echo Valley	Red Hook	Trib to Saw Kill	N/A	Insufficient	Past flooding location
32	Milan Hill Rd	Milan	Trib to Saw Kill	Moderate	<1-year flowrate	Walter et al. 2015
33	Milan Hill Rd	Milan	Trib to Saw Kill	Moderate	<1-year flowrate	Walter et al. 2015
34	Old Rock City Rd	Rhinebeck	Trib to Saw Kill	Moderate	<1-year flowrate	Walter et al. 2015
35	Oriole Mills Rd	Red Hook	Trib to Saw Kill	Moderate	<1-year flowrate	Walter et al. 2015
36	Norton Rd	Red Hook	Trib to Saw Kill	Moderate	<1-year flowrate	Walter et al. 2015
37	Chestnut St	Red Hook	Trib to Saw Kill	Moderate	<1-year flowrate	Walter et al. 2015
38	West Bard Ave	Red Hook	Trib to Saw Kill	Moderate	<1-year flowrate	Walter et al. 2015

N/A - Not Assessed

Crawford & Associates. 2017. Prioritization of culvert improvements with the Saw Kill watershed Town of Red Hook, Dutchess County, NY.

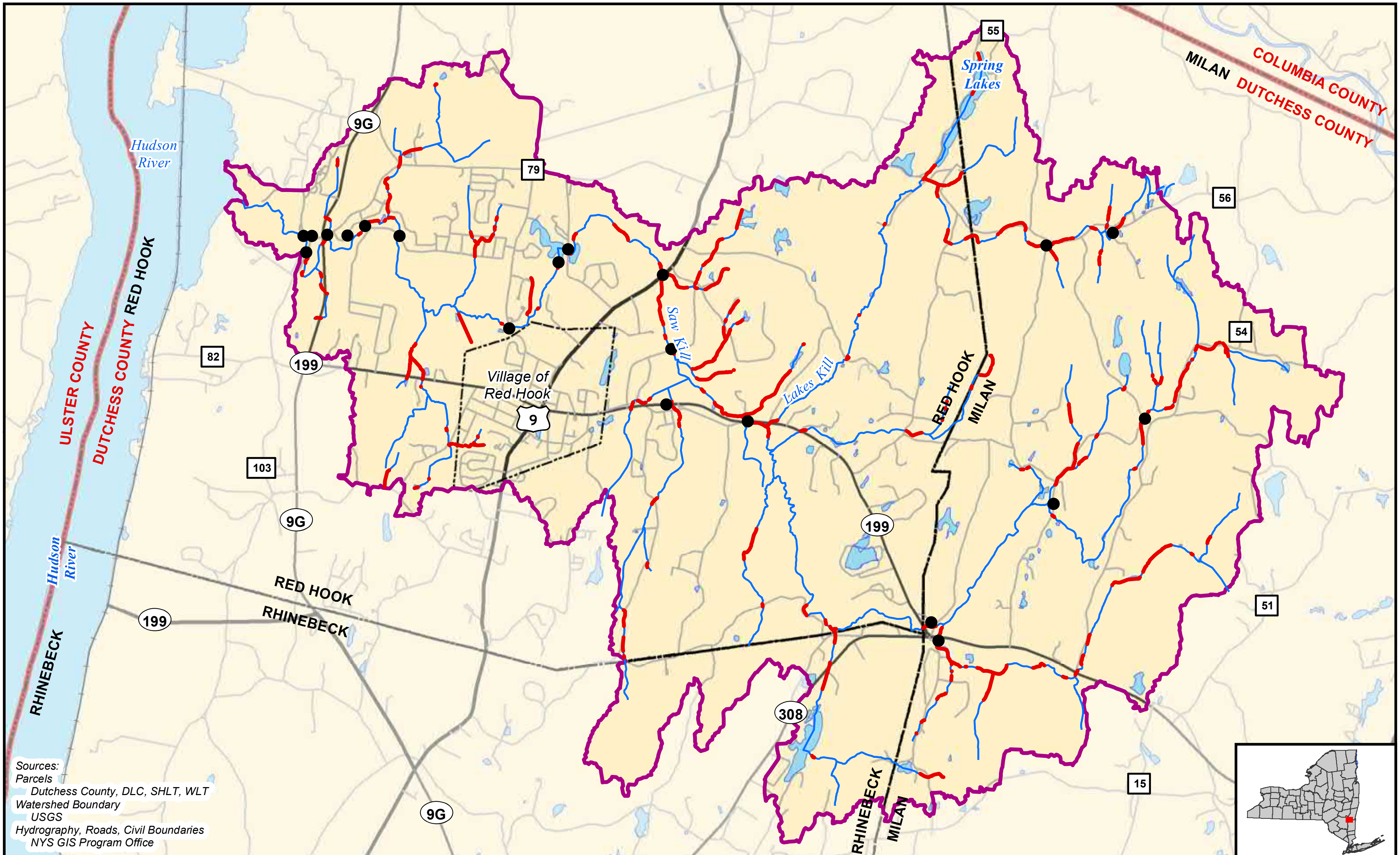
NYS DOT. 2017a. Hydraulic Summary of BIN 1040020.

NYS DOT. 2017b. Hydraulic Summary of BIN 1006440.

Walter, T, A DeGaetano, A Meyer, R Marjerison, D Gold, L Watkins. 2015. Determining peak flow under different scenarios and assessing organism passage potential: identifying and prioritizing undersized and poorly passable culverts. WRI Updates 2015-2016.

Potential Floodplain Reconnection Sites

Location	Comment	ParcelIDs
1	Aerial imagery and elevation data show evidence of berms which may limit floodplain access.	134889-6273-00-019222-0000 / 134889-6273-00-194131-0000
2	Aerial imagery and elevation data show evidence of previous channel straightening.	134889-6372-00-176735-0000 / 134889-6372-00-145794-0000 / 134889-6372-00-070930-0000
3	Old rail bed may prevent floodplain access; existing conservation easement; adjacent to habitat integrity area	134889-6373-00-674240-0000 / 134889-6373-00-729174-0000
4	Old rail bed may prevent floodplain access; adjacent to habitat integrity area	134889-6373-00-500340-0000
5	Floodplain potnetially be constricted by previous grading; excavate to increase flood storage; located within habitat integrity area	133600-6472-00-319257-0000 / 133600-6472-00-283203-0000 / 133600-6472-00-256170-0000
6	Incised channel located upstream of known flooding location; reconnect/restore floodplain under powerlines	133600-6472-00-492485-0000 / 133600-6472-00-482444-0000 / 133600-6472-00-523872-0000
7	Reconnect floodplain in forested area upstream	133600-6472-00-573155-0000 / 133600-6472-00-572071-0000



Potential Riparian Restoration Locations

Saw Kill Watershed

FUSS & O'NEILL

PROJ. No. 20161136.A1N

DATE: FEBRUARY 2018

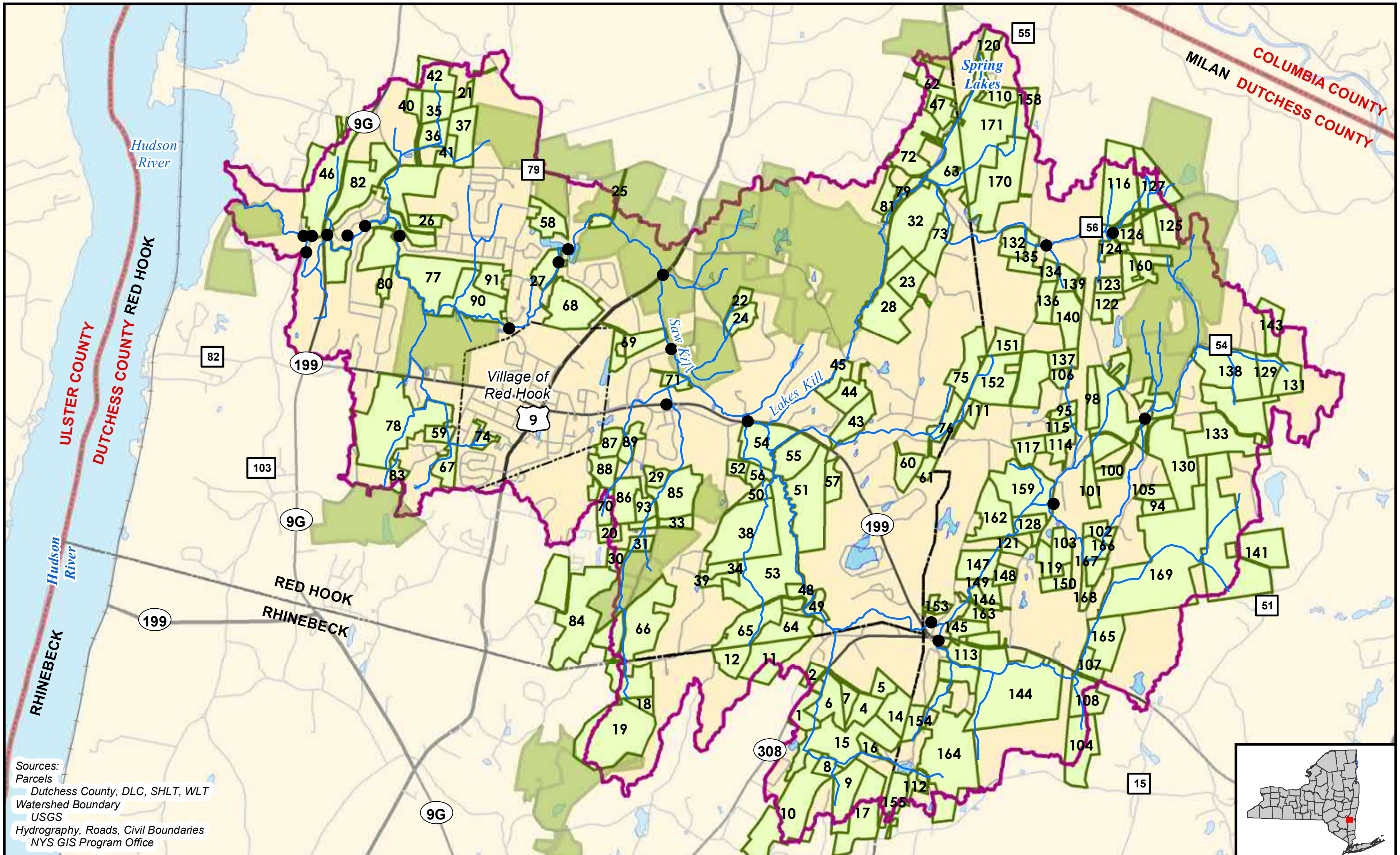
N W E S

0 0.5 1

Miles

- Past Flooding Locations
- Potential Restoration Sites
- Streams
- Surface Water
- Watershed Boundary

Path: K:\P2016\1136\A1N\MXD\SawKill_ParcelBased_Recommendations_Riparian.mxd



Potential Parcels For Conservation

Saw Kill Watershed

FUSS & O'NEILL

PROJ. No. 20161136.A1N

DATE: FEBRUARY 2018

N W E S

0 0.5 1 Miles

- Potential Conservation Parcel
- Existing Conserved Parcel
- Past Flooding Locations
- Streams
- Surface Water
- Watershed Boundary

Path: K:\P2016\1136\A1N\MXD\SawKill_ParcelBased_Recommendations_Conservation.mxd

Potential Parcels for Conservation

Label	Parcel ID	Acres
1	135089-00-6371-426548-0000	24.6
2	135089-00-6371-474680-0000	11.0
4	135089-00-6371-677551-0000	27.9
5	135089-00-6371-741635-0000	17.9
6	135089-00-6371-545578-0000	40.2
7	135089-00-6371-614587-0000	14.1
8	135089-00-6371-531328-0000	14.2
9	135089-00-6371-600224-0000	51.9
10	135089-00-6371-384151-0000	125.7
11	135089-00-6371-313740-0000	59.3
12	135089-00-6371-175747-0000	28.4
14	135089-00-6371-809539-0000	34.8
15	135089-00-6371-623445-0000	99.6
16	135089-00-6371-695399-0000	11.0
17	135089-00-6371-676159-0000	74.1
18	135089-00-6271-816570-0000	10.1
19	135089-00-6271-746511-0000	172.3
20	134889-00-6272-694235-0000	13.4
21	134889-00-6273-146920-0000	12.8
22	134889-00-6373-216134-0000	11.5
23	134889-00-6373-920175-0000	35.3
24	134889-00-6373-218065-0000	21.5
25	134889-00-6273-670450-0000	10.8
26	134889-00-6273-023456-0000	13.8
27	134889-00-6273-478274-0000	26.0
28	134889-00-6373-790095-0000	83.5
29	134889-00-6272-880450-0000	13.5
30	134889-00-6272-720140-0000	12.7
31	134889-00-6272-817196-0000	11.7
32	134889-00-6373-892440-0000	92.9
33	134889-00-6272-954273-0000	12.2
34	134889-00-6372-127094-0000	14.1
35	134889-00-6273-063888-0000	33.1
36	134889-00-6273-025785-0000	24.9
37	134889-00-6273-138760-0000	43.7
38	134889-00-6372-215250-0000	118.2
39	134889-00-6372-130065-0000	12.4
40	134889-00-6173-954901-0000	15.7
41	134889-00-6273-085713-0000	15.0
42	134889-00-6274-044064-0000	38.3
43	134889-00-6372-635655-0000	35.8
44	134889-00-6372-630768-0000	31.3
45	134889-00-6372-570815-0000	19.8
46	134889-00-6173-600630-0000	110.3
47	134889-00-6473-011869-0000	17.8
48	134889-00-6371-435988-0000	21.1
49	134889-00-6371-475935-0000	14.1
50	134889-00-6372-278387-0000	14.9
51	134889-00-6372-472345-0000	102.9
52	134889-00-6372-192491-0000	11.6
53	134889-00-6372-313070-0000	143.7
54	134889-00-6372-265605-0000	60.5
55	134889-00-6372-410537-0000	47.3
56	134889-00-6372-268448-0000	15.4
57	134889-00-6372-555426-0000	19.7
58	134889-00-6273-472440-0000	31.6
59	134889-00-6272-037624-0000	15.1
60	134889-00-6372-846490-0000	26.4
61	134889-00-6372-937511-0000	11.4
62	134889-00-6373-958965-0000	34.3

Label	Parcel ID	Acres
63	134889-00-6473-026648-0000	52.9
64	134889-00-6371-397857-0000	39.0
65	134889-00-6371-203885-0000	53.1
66	134889-00-6271-820860-0000	115.7
67	134889-00-6272-065498-0000	24.6
68	134889-00-6273-557128-0000	68.4
69	134889-00-6272-795956-0000	38.1
70	134889-00-6272-680337-0000	19.6
71	134889-00-6272-940828-0000	14.1
72	134889-00-6373-890737-0000	61.8
73	134889-00-6373-968349-0000	36.3
74	134801-09-6272-205603-0000	12.4
75	134889-00-6472-097883-0000	48.6
76	134889-00-6372-990636-0000	23.2
77	134889-00-6273-019222-0000	88.0
78	134889-00-6172-880670-0000	165.5
79	134889-00-6373-854555-0000	12.1
80	134889-00-6173-832202-0000	12.0
81	134889-00-6373-790535-0000	19.3
82	134889-00-6173-847544-0000	244.0
83	134889-00-6172-862490-0000	13.0
84	134889-00-6272-570015-0000	156.6
85	134889-00-6272-925355-0000	70.6
86	134889-00-6272-765360-0000	37.0
87	134889-00-6272-691583-0000	21.5
88	134889-00-6272-670468-0000	30.9
89	134889-12-6272-772580-0000	19.1
90	134889-00-6273-194131-0000	69.7
91	134889-00-6273-256221-0000	28.4
93	134889-00-6272-835332-0000	17.9
94	133600-00-6472-817319-0000	17.0
95	133600-00-6472-469695-0000	11.2
98	133600-00-6472-570751-0000	23.0
100	133600-00-6472-637453-0000	13.1
101	133600-00-6472-558422-0000	19.6
102	133600-00-6472-632225-0000	18.1
103	133600-00-6472-443142-0000	26.7
104	133600-00-6471-483315-0000	64.8
105	133600-00-6472-810372-0000	16.5
106	133600-00-6472-443823-0000	10.8
107	133600-00-6471-542699-0000	16.4
108	133600-00-6471-540601-0000	40.4
110	133600-00-6473-222924-0000	19.6
111	133600-00-6472-104684-0000	10.6
112	133600-00-6371-866260-0000	11.0
113	133600-00-6471-052760-0000	23.3
114	133600-00-6472-441551-0000	25.5
115	133600-00-6472-440640-0000	11.3
116	133600-00-6473-662588-0000	92.0
117	133600-00-6472-323546-0000	23.8
119	133600-00-6472-372151-0000	18.1
120	133600-00-6474-175125-0000	16.3
121	133600-00-6472-256170-0000	12.0
122	133600-00-6473-611096-0000	22.1
123	133600-00-6473-630185-0000	14.3
124	133600-00-6473-664329-0000	12.9
125	133600-00-6473-868413-0000	27.0
126	133600-00-6473-713387-0000	10.2
127	133600-00-6473-797586-0000	56.9
128	133600-00-6472-319257-0000	19.3

Potential Parcels for Conservation

Label	Parcel ID	Acres
129	133600-00-6572-247838-0000	24.4
130	133600-00-6472-725629-0000	228.1
131	133600-00-6572-323814-0000	26.9
132	133600-00-6473-267354-0000	24.9
133	133600-00-6572-133627-0000	140.9
134	133600-00-6473-406238-0000	10.3
135	133600-00-6473-336309-0000	23.7
136	133600-00-6473-396134-0000	22.9
137	133600-00-6472-494889-0000	18.0
138	133600-00-6572-113884-0000	88.8
139	133600-00-6473-473209-0000	16.1
140	133600-00-6473-500047-0000	49.9
141	133600-00-6572-081196-0000	224.5
143	133600-00-6573-263009-0000	30.4
144	133600-00-6471-252633-0000	214.3
145	133600-00-6471-074855-0000	20.1
146	133600-00-6471-134958-0000	12.4
147	133600-00-6472-115102-0000	39.4
148	133600-00-6472-227046-0000	13.3
149	133600-00-6471-169987-0000	14.4
150	133600-00-6472-430031-0000	17.7
151	133600-00-6472-240964-0000	24.7
152	133600-00-6472-251824-0000	116.7
153	133600-00-6371-959940-0000	10.5
154	133600-00-6371-868496-0000	18.6
155	133600-00-6371-785177-0000	31.3
158	133600-00-6473-295840-0000	29.5
159	133600-00-6472-302392-0000	87.5
160	133600-00-6473-785266-0000	39.9
161	133600-00-6473-807405-0000	17.2
162	133600-00-6472-174298-0000	55.2
163	133600-00-6471-090924-0000	13.5
164	133600-00-6471-025504-0000	195.9
165	133600-00-6471-606802-0000	53.0
166	133600-00-6472-573155-0000	18.4
167	133600-00-6472-572071-0000	14.1
168	133600-00-6471-521975-0000	11.7
169	133600-00-6472-875130-0000	261.5
170	133600-00-6473-236616-0000	102.2
171	133600-00-6473-124796-0000	133.9

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