New York City Department of Environmental Protection

Bureau of Water Supply

Stream Management Program
Stony Clove Watershed Suspended Sediment and Turbidity Study:
Turbidity Reduction Project Nomination Report

January 2019

Prepared in accordance with Section 4.6 of the NYSDOH

2017 Filtration Avoidance Determination

Prepared by: DEP, Bureau of Water Supply

1. Introduction

The 2017 Filtration Avoidance Determination (FAD) requires the New York City Department of Environmental Protection (DEP) Stream Management Program (SMP) to design and implement turbidity and suspended sediment source characterization and reduction research in the Esopus Creek watershed. The 2017 FAD further requires the SMP to construct and monitor the water quality impact of three stream projects in the Stony Clove watershed as part of this research. This report nominates three priority projects for treatment and identifies two additional projects as potential alternatives, in the event they are needed.

The collaborative 10-year study between DEP and the U.S. Geological Survey (USGS) is underway to characterize suspended sediment and turbidity source dynamics within the upper Esopus Creek watershed, and to monitor results of sediment turbidity reduction projects (STRPs) in the Stony Clove watershed. The USGS monitors discharge, suspended sediment, and turbidity spanning stream reach to reservoir watershed scales. Stream channel geologic and geomorphologic sediment source investigations, streambank erosion monitoring, and sediment source fingerprinting help relate watershed sediment source dynamics to measured suspended sediment and turbidity levels. The combination of water quality monitoring and sediment source characterization is used to identify stream reaches that contribute measurable turbidity levels that can be targeted for STRPs.

Figure 1 depicts the USGS discharge/water quality monitoring stations and current bank erosion monitoring sites (BEMS) in the Stony Clove watershed. The USGS monitoring stations delineate stream reaches where geologic and geomorphologic investigations occur (Figure 2). The water quality monitoring network is further used to evaluate the effectiveness of existing and future STRPs at a range of spatial, temporal and hydrologic scales (Figure 3).

DEP has selected candidate STRP sites based on a review of turbidity monitoring data for the period spanning October 2016 to September 2018 and interpretation of available geologic and geomorphologic characterization. Site prioritization includes relative measured turbidity contribution, treatable geomorphic conditions, multi-objective benefits, and construction feasibility.

This report is organized to present the recommended STRPs for the Stony Clove watershed targeted for construction during 2020–2021 in priority order, with the top three nominated sites described first (SCC1, WC1, and WC2), followed by the two alternative sites (WC3 and SCC2) also being described and recommended in the event they are needed.

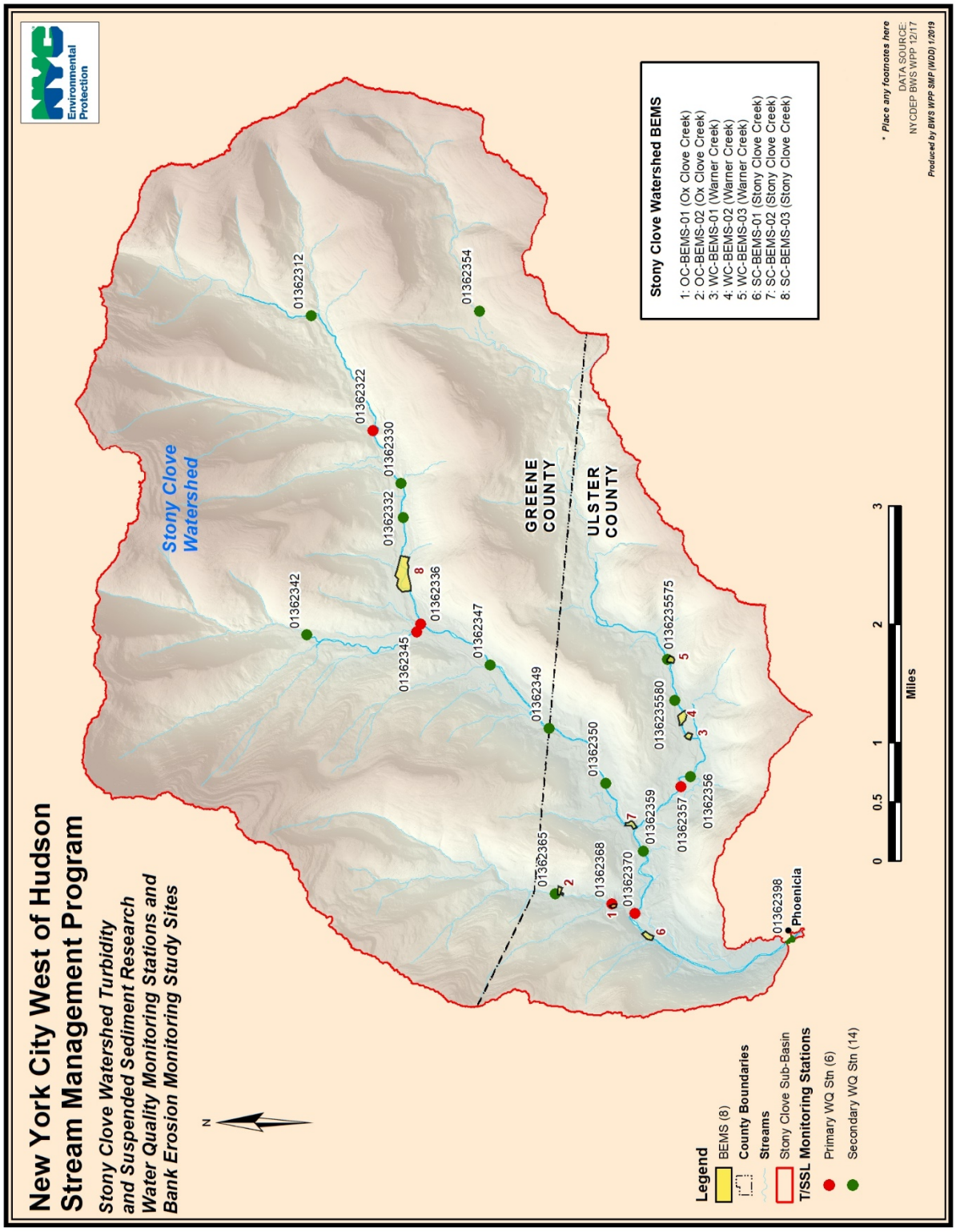

Figure 1. USGS water quality monitoring stations and BEMS locations in the Stony Clove watershed.

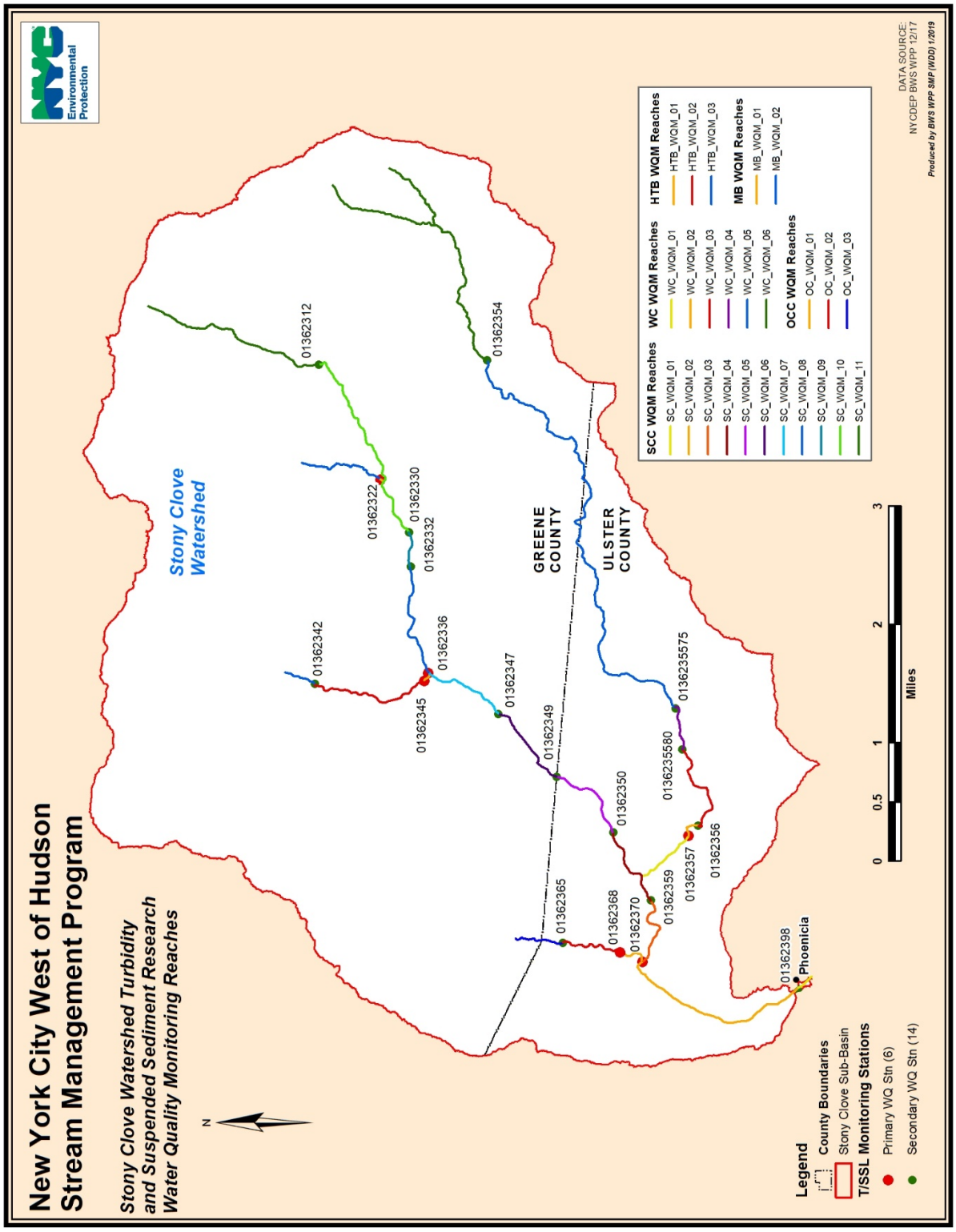

Figure 2. Water Quality Monitoring Reaches in the Stony Clove watershed as delineated by USGS monitoring stations.

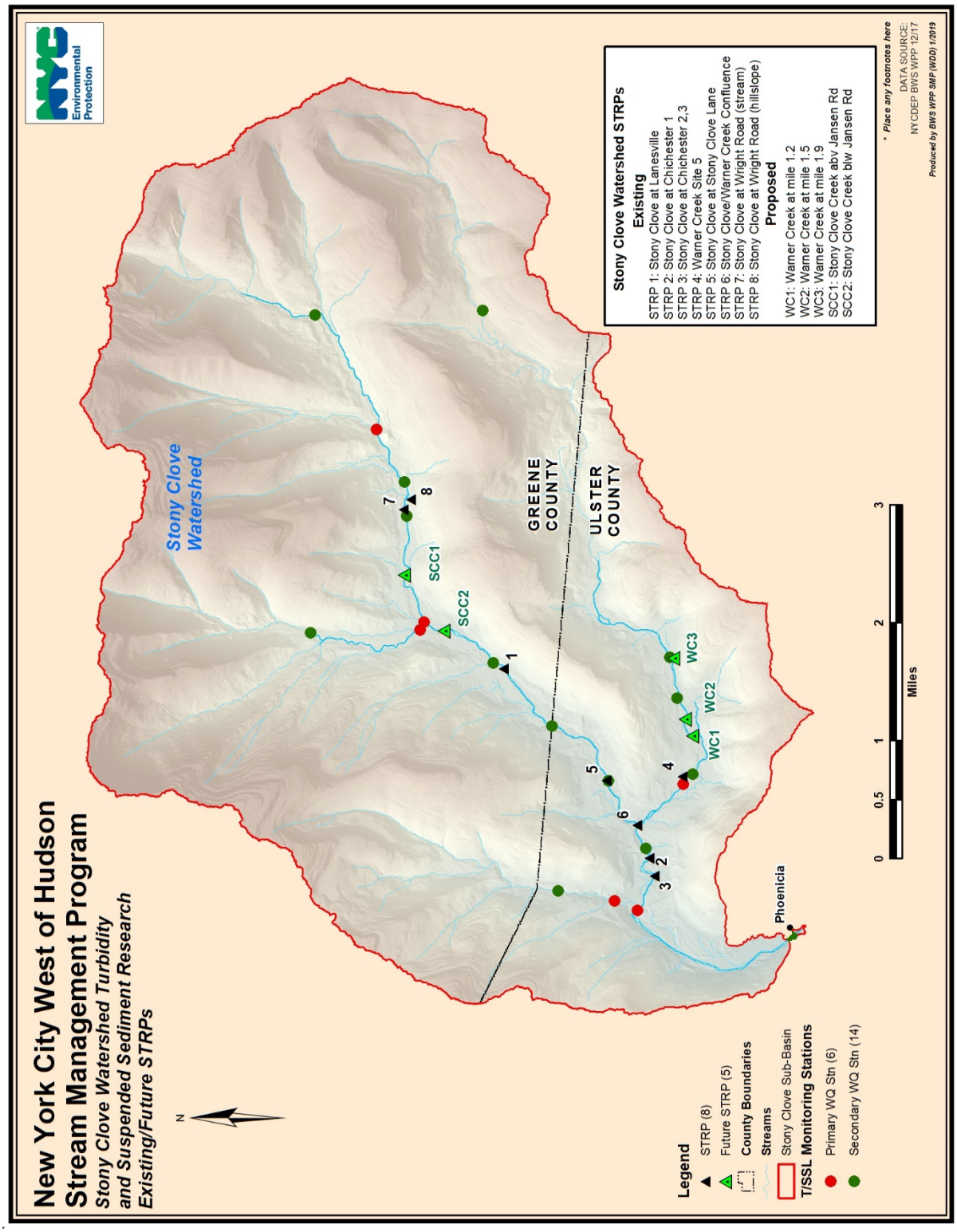

Figure 3. Location of existing and potential future STRPs in the Stony Clove watershed.

2. Candidate Stony Clove Watershed STRP Sites

Based on available water quality monitoring data and observed geologic and geomorphic conditions, DEP recommends the following priority STRP sites for approval by the New York State Department of Health (NYSDOH). The first three sites are officially nominated as the three highest priorities, followed by two alternate sites as the next set of priorities.

SCC1 – Stony Clove Creek above Jansen Road (Priority Site)

This site is located along NYS Route 214 in the Town of Hunter, Greene County, and spans two private parcels. One parcel accounts for the primary turbidity source condition and is currently in the process of being acquired by the City. The approximately 1600-foot section of stream is located approximately 5.7–6 miles upstream from the confluence with Esopus Creek (Figure 4). The probable STRP extents may cover up to 11 acres.

The stream has extensive erosional contact with glacial lake sediment (silt and clay) along the right channel margin and in the streambed (Figure 5). Active hydraulic and geotechnical erosion were mapped here in 2013 and again in 2018, following a flood-induced avulsion in August 2011. STRP treatment at this site is expected to have a measurable reduction in turbidity by removing the channel from erosive contact with the glacial lake sediment.

The site is one of eight BEMS in the Stony Clove watershed (SC-BEMS-03). Since April 2018 there has been one round of topographic survey monitoring documenting channel geomorphic conditions (Table 4). Additional survey monitoring is planned for April 2019.

WC1 – Warner Creek at mile 1.2 (Priority Site)

This site is located along Silver Hollow Road in the Town of Shandaken, Ulster County, and spans two private parcels. This approximately 540-foot section of stream is located approximately 1.2 miles upstream from the confluence with Stony Clove Creek (Figure 6). The probable STRP extents are likely to cover 1.5 to 2.0 acres.

The stream has extensive erosional contact with glacial lake sediment along the right channel margin and in the streambed (Figure 7). Active hydraulic and geotechnical erosion have been repeatedly mapped here since 2010. STRP treatment at this site is expected to have a measurable reduction in turbidity by removing the channel from erosive contact with the glacial lake sediment. In addition to turbidity source reduction, the site is impacting a residential property and has the potential to impact Silver Hollow Road through mass wasting encroachment on the road.

The site is one of the eight BEMS in the Stony Clove watershed (WC-BEMS-01). Since November 2016 there have been four rounds of topographic survey monitoring documenting channel geomorphic adjustment (Table 4).

WC2 – Warner Creek at mile 1.5 (Priority Site)

This site is located along Silver Hollow Road in the Town of Shandaken, Ulster County, and spans two private parcels. This approximately 560-foot section of stream is located approximately 1.5 miles upstream from the confluence with Stony Clove Creek (Figure 6). The probable STRP extents are shown on Figure 6 and are likely to cover 1.5 to 2.0 acres.

The stream has extensive erosional contact with glacial lake sediment along the left channel margin and in the streambed (Figure 8). Active hydraulic and geotechnical erosion have been repeatedly mapped here since 2010 following a flood-induced avulsion in January 2010. STRP treatment at this site is expected to have a measurable reduction in turbidity by removing the channel from erosive contact with the glacial lake sediment.

The site is one of the eight BEMS in the Stony Clove watershed (WC-BEMS-02). Since November 2016 there have been four rounds of topographic survey monitoring documenting channel geomorphic adjustment (Table 4).

WC3 – Warner Creek at mile 1.9 (Alternate Site)

This site is located at the end of Silver Hollow Road in the Town of Shandaken, Ulster County, and is located on State-owned land designated as Catskill Forest Preserve. Since the location on State land may preclude this site from implementation, it is considered an alternate site in case one of the three priority sites cannot be constructed. This 540-foot long section of stream is located approximately 1.9 mi upstream from Stony Clove Creek along NYS property designated as Forest Preserve (Figure 9). It is located approximately 0.6 mi upstream of WC 2. The probable STRP extents are shown on Figure 9 and may cover 1.5 to 2.0 acres.

The stream has erosional contact with glacial lake sediment (silt and clay) along the left channel margin and in the streambed associated with a mass failure triggered by hydraulic erosion on the outside of a meander bend (Figure 10). Active hydraulic and geotechnical erosion have been repeatedly mapped here since 2010. This is the known upstream most source of chronic turbidity in Warner Creek at this time. STRP treatment at this site is expected to have a measurable reduction in turbidity by removing the channel from erosive contact with the glacial lake sediment.

The site is one of the eight BEMS in the Stony Clove watershed (WC-BEMS-03). Since July 2017 there have been two rounds of topographic survey monitoring documenting channel geomorphic adjustment (Table 4).

SCC2 – Stony Clove Creek below Jansen Road (Alternate Site)

This site is a recommended alternative in the event that reported turbidity values at the downstream monitoring station are verified and if one of the other priority sites is not feasible. The site is located along NYS Route 214 in the Town of Hunter, Greene County, and potentially spans 17 parcels. Based on 2018 mapping of erosional contact with suspended sediment source material potential STRP site extents are 2100 feet and 8–9 acres located approximately 5–5.4

miles upstream of the confluence with Esopus Creek (Figure 11). Further investigation is needed to determine actual location and STRP dimensions.

This reach of stream between the monitoring stations has intermittent erosional contact with glacial lake sediment in the streambed at the upstream extent and along the left channel margin in the downstream extent (Figure 11 and Figure 12). Extensive post-flood modification of approximately 1200 feet of the channel about 650 feet downstream of the Jansen Road bridge occurred following Tropical Storm Irene flooding in 2011. This work resulted in several exposures of glacial lake clay in the streambed that have transiently recurred. Based on the water quality monitoring so far, STRP treatment at this site is expected to have a measurable reduction in turbidity by removing the channel from erosive contact with the glacial lake sediment. The site is not one of the eight BEMS in the Stony Clove watershed. The only assessment work completed to date has been the repeated stream feature inventory (SFI) mapping, so further investigation is needed to better characterize suspended sediment source conditions.

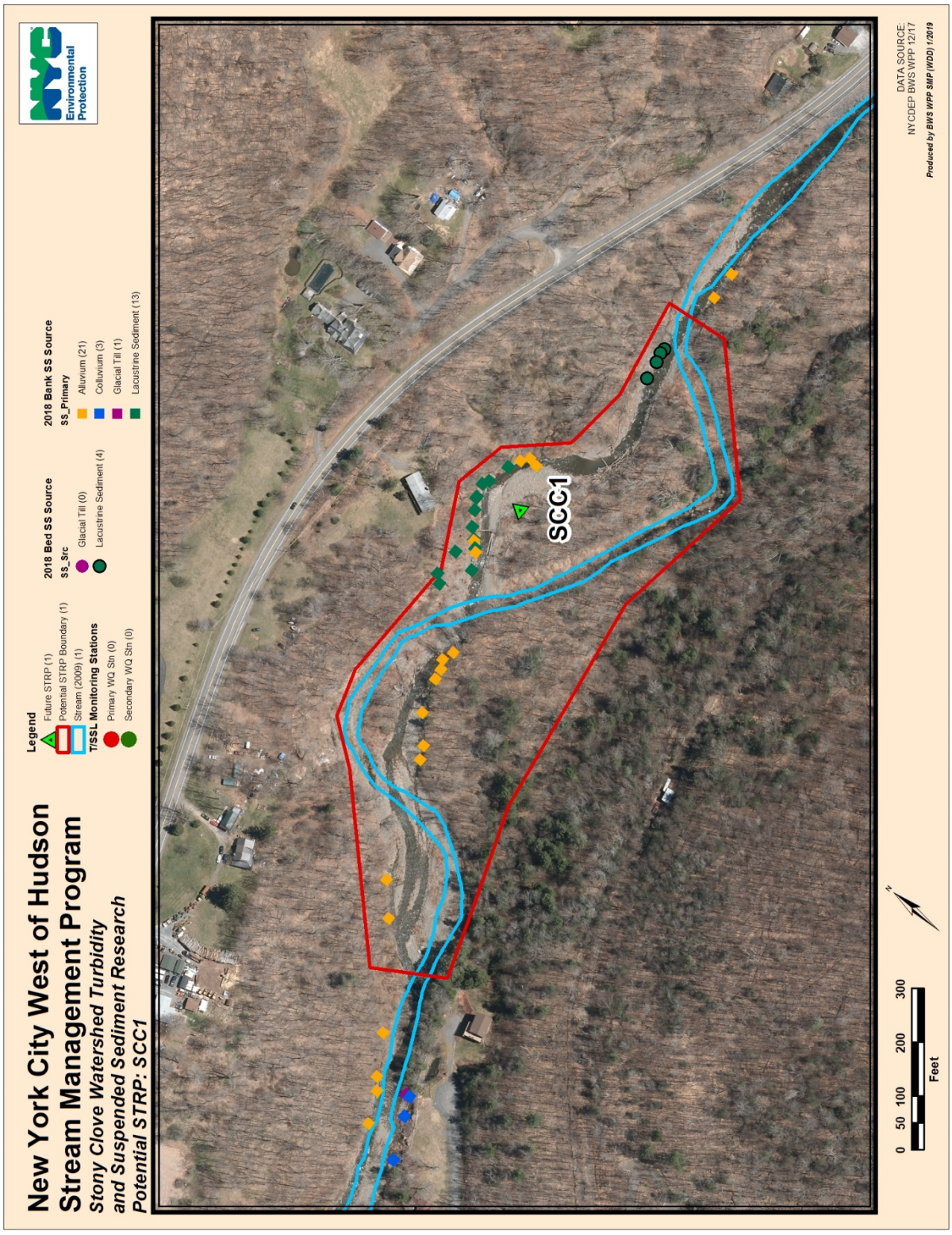

Figure 4. Location of SCC1 site on Stony Clove Creek. Aerial imagery is from April 2016. Blue outline is the boundary for Stony Clove Creek in 2009. Provisional 2018 SFI data is posted for reference to mapped suspended sediment sources.

Figure 5. Documentation of SCC1 site at SC-BEMS-03 on Stony Clove Creek. Photo A depicts the mass failure of glacial lake sediment and high terrace alluvium. Photo B depicts terrace alluvium collapsed over underlying glacial lake sediment. Photo C Provides a close-up of view of mass-wasted glacial lake sediment on the channel margin. Photo D illustrates water quality impact of glacial lake sediment in bank toe and streambed at outside of meander bend.

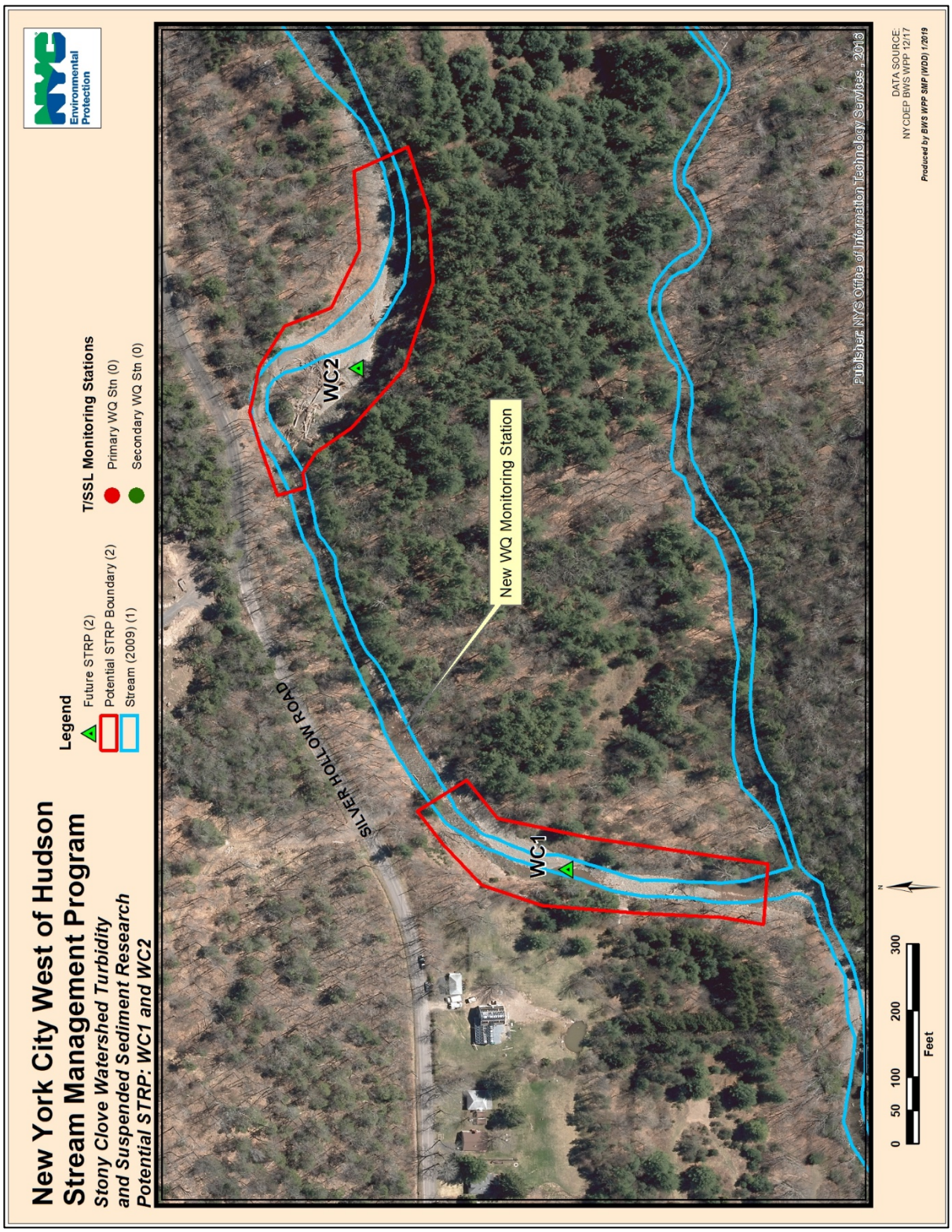

Figure 6. Location of WC1 and WC2 sites on Warner Creek. Aerial imagery is from April 2016. Blue outline is the boundary for Warner Creek in 2009.

Figure 7. Documentation of WC1 site at WC-BEMS-01 on Warner Creek. Photo A depicts turbid scour pool into glacial lake sediment on outside of meander bend. Photo B depicts exposed glacial lake sediment along bank. Photo C depicts mass wasting glacial lake terrace capped by alluvium. Photo D provides a close-up of stream-turbidity source contact.

Figure 8. Documentation of WC2 site at WC-BEMS-02 on Warner Creek. Photo A depicts mass failure of glacial lake sediment and terrace alluvium. Photo B depicts where the stream is eroding into glacial lake sediment. Photo C illustrates the mass wasting terrace with glacial lake sediment exposed in the channel margin. Photo D illustrates headcut into glacial lake sediment in streambed.

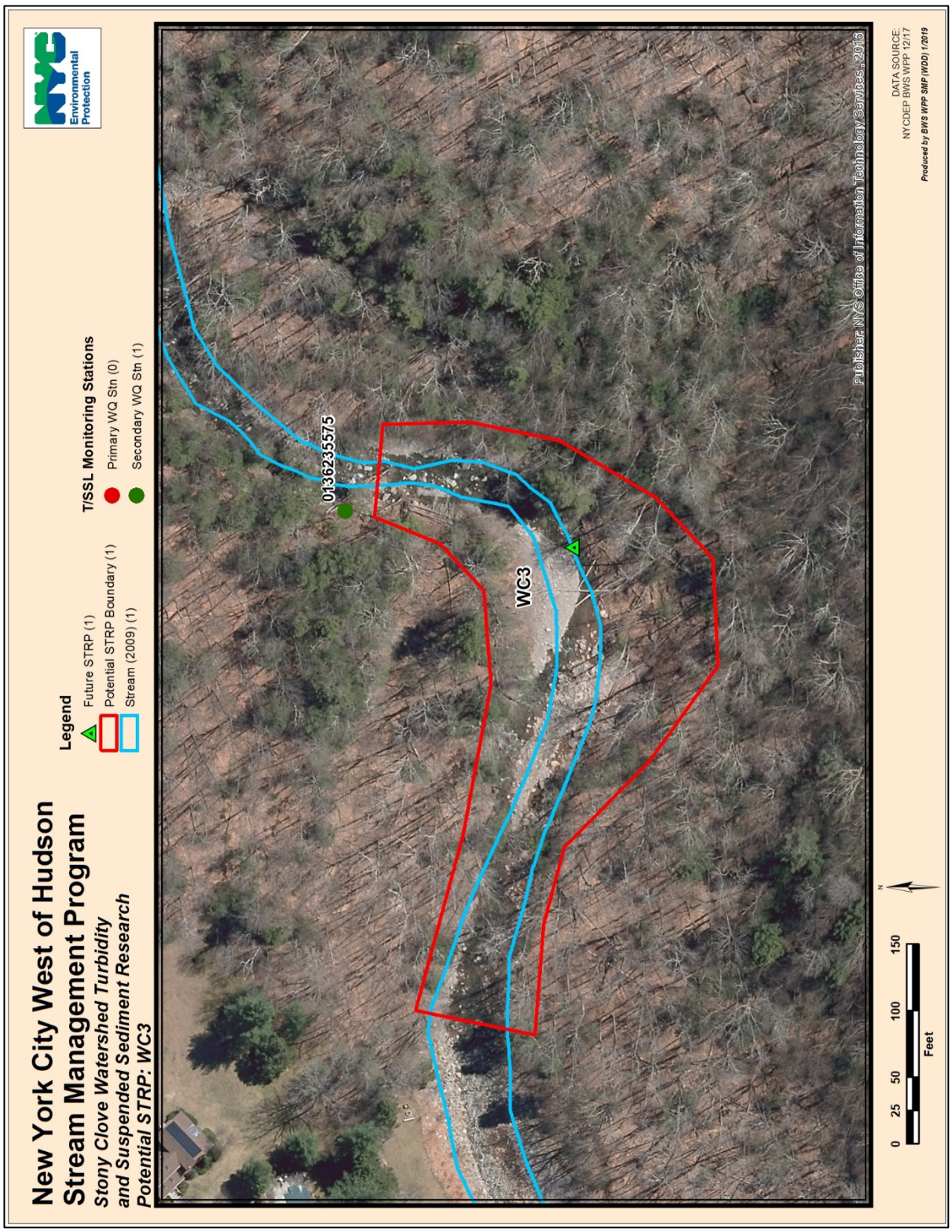

Figure 9. Location of WC3 site on Warner Creek. Aerial imagery is from April 2016. Blue outline is the boundary for Warner Creek in 2009.

Figure 10. Documentation of WC3 site located at WC-BEMS-03 on Warner Creek. Photo A depicts mass failure of glacial lake sediment, glacial till and terrace alluvium. Photo B illustrates where the stream becomes turbid from contact with glacial lake sediment. Photo C illustrates mass wasting slope on outside of meander bend with high near bank shear stress.

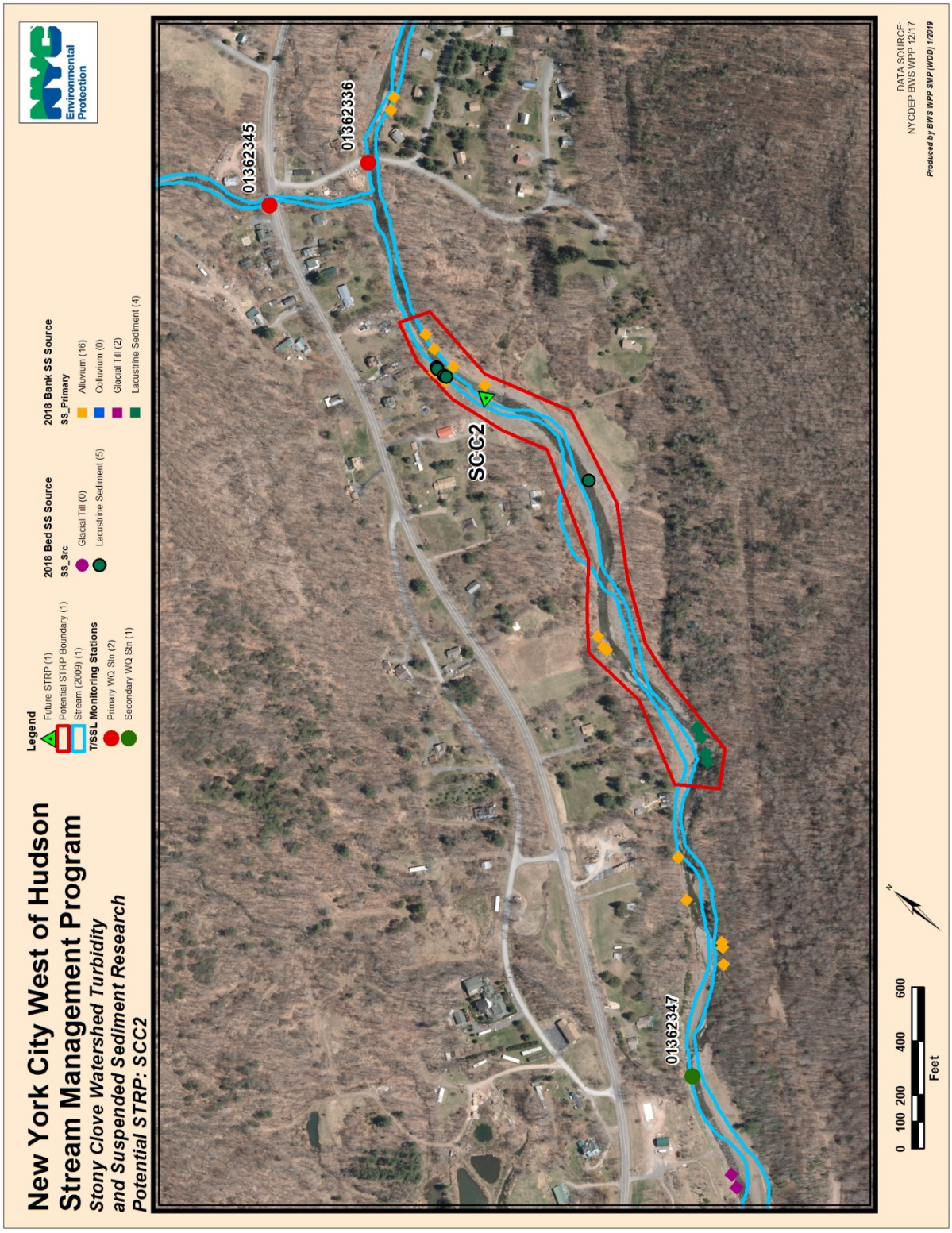

Figure 11. Location of SCC2 site on Stony Clove Creek. Aerial imagery is from April 2016. Blue outline is the boundary for Stony Clove Creek in 2009. Provisional 2018 SFI data is posted for reference to mapped suspended sediment sources.

Figure 12. Documentation of SCC2 site on Stony Clove Creek. Photo A depicts a bed exposure of glacial lake sediment. Photo B depicts the entrenched channelized channel. Photo C depicts channelized channel. Photo D was taken after Tropical Storm Irene flooding but before post-flood channelization.

3. Data and Analysis Supporting Site Selection

DEP used provisional turbidity data from USGS monitoring stations for water years 2017 and 2018 to identify water quality monitoring reaches that contribute measurable amounts of turbidity. DEP selected candidate STRP sites within the turbidity contributing reaches based on interpretation of geomorphic/geologic assessment and monitoring data from 2010–2018.

Water Quality Monitoring Data

The USGS maintains 20 water quality monitoring stations distributed throughout the Stony Clove watershed that DEP used to delineate 25 water quality monitoring reaches (Figure 1; Table 1 and Table 2). Six of the stations measure turbidity and stage-discharge every 15 minutes and are instrumented for automated and manual suspended sediment sampling during storm runoff events. These are "primary" stations for obtaining measurements of suspended sediment load and yield. There are two primary stations on Stony Clove Creek (SCC) and one for each of the four main tributary streams: Ox Clove Creek (OCC), Warner Creek (WC), Hollow Tree Brook (HTB), and Myrtle Brook (MB). Fourteen of the stations measure only turbidity every 15 minutes. These are "secondary" stations for obtaining turbidity levels and estimating suspended sediment load and yield using estimated discharge and suspended sediment concentration-turbidity relationships established at the primary stations.

For the purpose of STRP candidate site selection, the USGS provided DEP with the following provisional data:

- Turbidity monitoring data for water years 2017 and 2018. See Figures 13-17 for turbidity box plots of the daily mean turbidity (DMT) values for all Stony Clove watershed monitoring stations. There are two plots for each stream: one representing the full range of values and one excluding the upper quartile to highlight differences between stations at low to moderate turbidity levels.
- Turbidity monitoring data for two storm events for the SCC and WC monitoring stations in water year 2018: July 23-27, 2018; and August 17-21, 2018. See Figures 18-21 for turbidity box plots of the instantaneous turbidity values for each event. Full range and lower quartile range plots are presented for each stream and storm.

It is important to note that the USGS data is considered provisional and subject to change upon completion of annual turbidity probe calibration results and USGS quality assurance/quality control procedures. Given this status, DEP limited analysis to basic interpretations of these simplified plots of the available turbidity data. The suspended sediment concentration data is not ready for computation of reach-scale to basin-scale sediment load and yield. Subsequent reporting in March 2019 may include more advanced analysis of the turbidity, discharge, and available suspended sediment data pending completion of USGS quality control procedures. If substantive changes in the data and/or interpretation occur that would modify the findings in this report, DEP will provide an updated report.

Daily Mean Turbidity Data Box Plots for Water Years 2017 and 2018

- HTB (Figure 16) and MB (Figure 17) are not substantive turbidity sources in the Stony Clove watershed during the monitoring period and therefore DEP does not propose STRPs for these streams.
- OCC, WC, and SCC are evident turbidity sources in the Stony Clove watershed during the monitoring period, though WC and SCC significantly exceed OCC as a source of turbidity (Figures 13-15). Therefore, WC and SCC are the priority streams for STRPs.
- There are 10 monitoring stations delineating 11 monitoring reaches on SCC and five monitoring stations delineating six monitoring reaches on WC (Figure 1). Clear differences in the range of DMT values for the monitoring reaches allows for identifying both the upstream extent of higher levels of turbidity production and differentiation of monitored reach "contributions" to the turbidity observed in each stream.
- On SCC, DEP has identified three water quality monitoring reaches that exhibit notable upstream to downstream increases in DMT.
    - The first notable increase in DMT values is in reach SC-WQM-08 recorded at the downstream station 01362336 (Figure 2 and Figure 13) indicating the presence of erosional suspended sediment sources in this reach. Approximately 36% of the assessed portion of SCC is upstream of SC-WQM-08 and for the monitoring period is not considered a significant source of turbidity for the purpose of STRP implementation.
    - The adjacent downstream reach SC-WQM-07 exhibits a significant increase in DMT values as recorded at the downstream station 01362347 (Figure 2 and Figure 13) indicating the presence of erosional suspended sediment sources in this reach. The USGS currently advises that the probe at 01362347 still needs to be calibrated and these values may change. The fact that reach SC-WQM-06 bounded by downstream station 01362349 has notably lower values indicates that a recalibrated probe may result in lower values for SC-WQM-07 (Figure 13).
    - The next substantial increase in the DMT values is for reach SC-WQM-05 bounded by downstream station 01362350 (Figure 2 and Figure 13) indicating the presence of erosional suspended sediment sources in this reach. However, the very high DMT values seem largely attributable to the fact that the probe is measuring turbidity too close to an observed source to allow for sufficient mixing of the turbidity plume with upstream water, resulting in an unrepresentative turbidity value. DEP and USGS are investigating feasible alternative locations for this station.
    - DMT for water years 2017 and 2018 does not substantially increase for the water quality-delineated reaches downstream of station 01362350, though there is an incremental increase between each of the three downstream stations indicating

additional stream corridor turbidity sources (including contributions from WC and OCC).

- On WC, DEP has identified three water quality reaches that exhibit notable upstream to downstream increases in DMT:
    - The first notable increase in DMT values is in reach WC-WQM-04 as recorded at downstream station 0136235580 (Figure 2 and Figure 14) indicating the presence of erosional suspended sediment sources in this reach. Approximately 79% of the assessed portion of WC is upstream of WC-WQM-04 and for the monitoring period is not considered a significant source of turbidity for the purpose of STRP implementation.
    - There is an increase in the upper quartile DMT values through reach WC-WQM-03 bounded by downstream station 01352356, yet, the difference in the mean value is negligible (Figure 2 and Figure 14). This indicates that erosional suspended sediment sources are present but not actively contributing sediment for the full range of monitored flows.
    - Reach WC-WQM-02 exhibits a notable increase in the full range of DMT values. This reach includes the 2013 STRP "Warner Creek Site 5". The elevated turbidity values indicate that there is still a turbidity source associated with this treated reach.

Storm Event Turbidity Data Box Plots

Storm event turbidity box plots collapse the time series data into quartile ranges (similar to the water year turbidity box plots) and readily display the relative differences in turbidity magnitude from station-to-station for each storm. Unfortunately, missing data for SCC station 01362336 during the August 2018 storm limits the interpretation for reach SC-WQM-08. Using this available data, DEP offers the following observations:

- Different storms tell different sources stories.
- For SCC:
    - The turbidity box plots show that in both storms there is an increase in turbidity for reach SC-WQM-08 recorded at 01362336 and an increase for reach SC-WQM-07 recorded at 01362347 (Figures 18-21). The substantively lower turbidity values for reach SC-WQM-06 recorded at 01362349 implies that the elevated values at 01362347 may not be actual. Probe calibration and testing will determine if the values need to be corrected or if there may be other phenomena influencing the turbidity values. Further investigation is needed.
    - The turbidity box plots for the two storms show that reach SC-WQM-05 bounded by downstream station 01362350, recorded elevated turbidity for the July 2018

storm but not the August 2018 storm. A review of the time series data (not presented in this report) finds that the high values for the July 2018 storm at station 01362350 are just prior to the rising runoff flood stage. This further supports the conclusion that the probe is recording an unmixed plume of suspended sediment from rainfall-runoff over a mass wasted slope just upstream of the monitoring station.

  - The August 2018 storm turbidity box plot shows a substantial increase in the moderate turbidity values for reach SC-WQM-04 recorded at station 01362359 located downstream of the WC confluence (Figure 19). A review of the August 2018 storm data for WC finds that WC is the probable source of this increase in turbidity in SCC during this storm event.

- For WC:

  - The turbidity box plots show that in both storms there is an increase in turbidity for reach WC-WQM-04 recorded at station 0136235580 (consistent with the mean daily plots); however, the August 2018 storm data shows a substantial increase in turbidity at the upstream bounding station 0136235575. The turbidity sources for these elevated values are not known at the time of this reporting.

  - Reach WC-WQM-03 shows different responses to the two storm events. There is minimal difference between WC-WQM-03 and WC-WQM-04 for the July 2018 storm in the box plots (Figure 20). The contrast between the two reaches is much clearer in the August 2018 event (Figure 21) with notably elevated turbidity values in WC-WQM-03.

  - Station 01352357 at the downstream end of WC-WQM-02 does not show an increase in turbidity for the July 2018 storm (Figure 20) but does show a notable increase for the August 2018 storm (Figure 21).

Based on the water quality monitoring data we identified six potential water quality monitoring delineated reaches for STRP candidate site selection:

- In Stony Clove Creek: SC-WQM-08, SC-WQM-07 and SC-WQM-05.
- In Warner Creek: WC-WQM-04, WC-WQM-03 and WC-WQM-02.

If turbidity sources can be identified and can be mitigated, future STRPs in these turbidity monitored reaches would presumably have a measurable reduction in turbidity. The next section in this report discusses the availability and interpretation of geomorphic and geologic data to further turbidity source identification and STRP site selection.

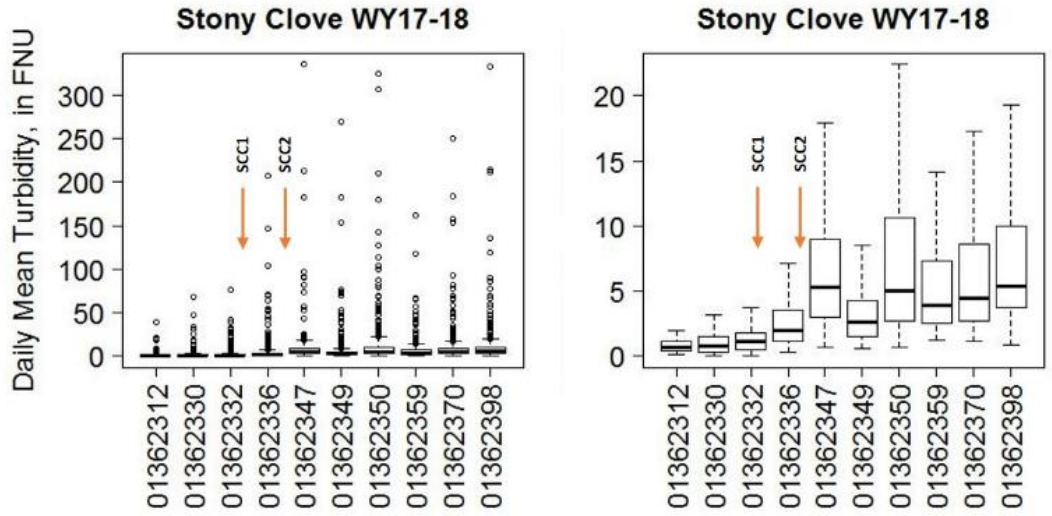

Figure 13. Turbidity box plots for Stony Clove Creek monitoring stations for the period of October 1, 2016 – September 30, 2018. The left plot is for the full range of mean daily mean turbidity values; the right plot is for mean daily turbidity values in the lower quantile range. Arrows with labels indicate location of monitored reaches with potential future STRPs.

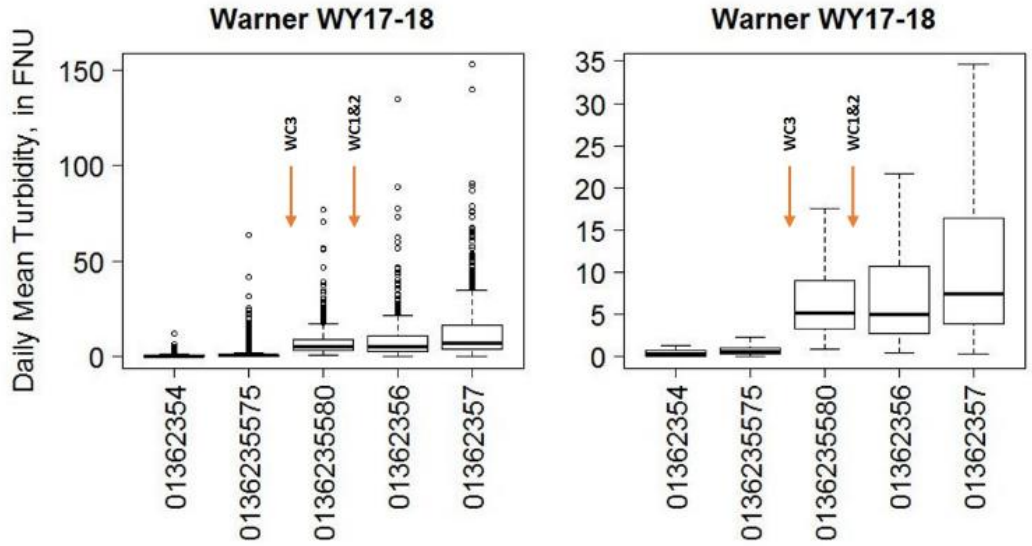

Figure 14. Turbidity box plots for Warner Creek monitoring stations for the period of October 1, 2016 – September 30, 2018. The left plot is for the full range of mean daily mean turbidity values; the right plot is for mean daily turbidity values in the lower quantile range. Arrows with labels indicate location of monitored reaches with potential future STRPs.

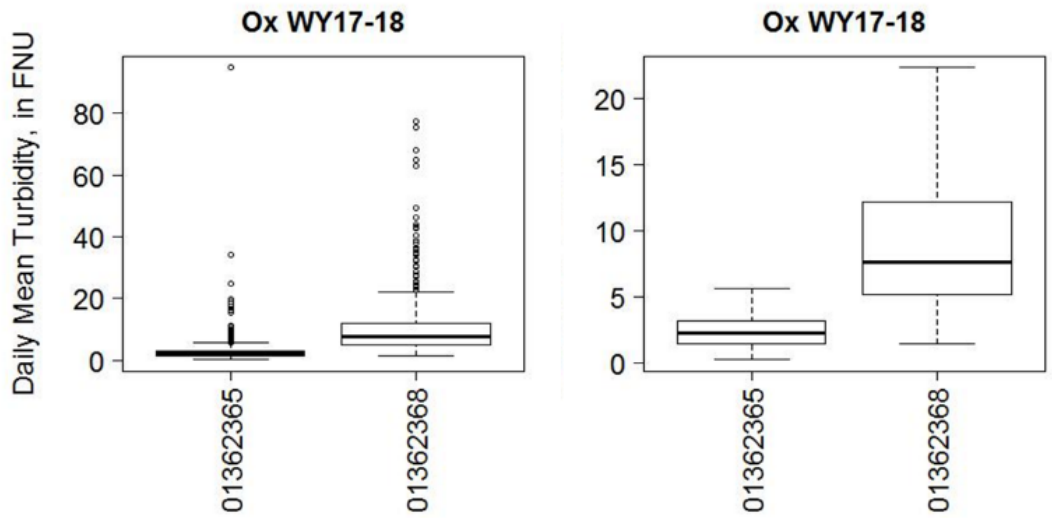

Figure 15. Turbidity box plots for Ox Clove Creek monitoring stations for the period of October 1, 2016 – September 30, 2018. The left plot is for the full range of mean daily mean turbidity values; the right plot is for mean daily turbidity values in the lower quantile range.

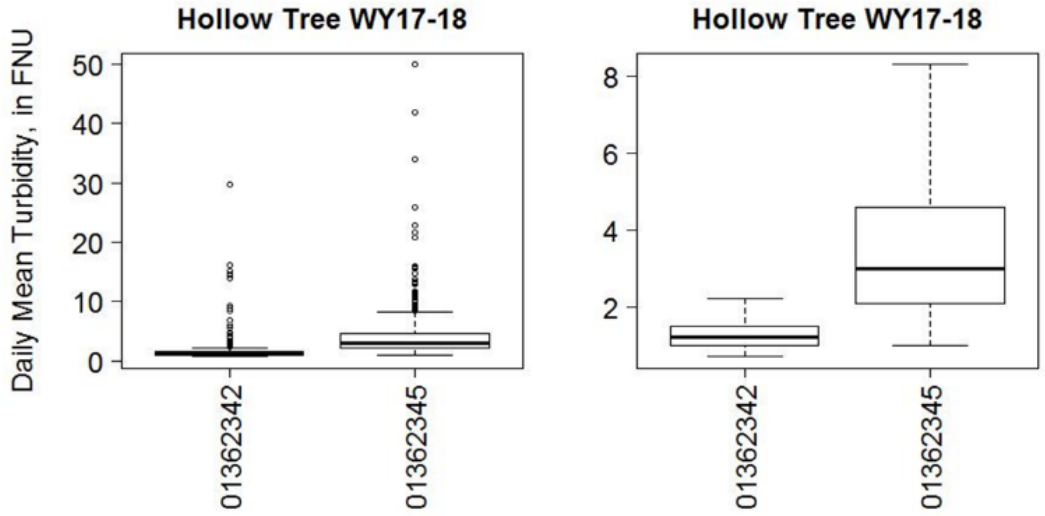

Figure 16. Turbidity box plots for Hollow Tree Brook monitoring stations for the period of October 1, 2016 – September 30, 2018. The left plot is for the full range of mean daily mean turbidity values; the right plot is for mean daily turbidity values in the lower quantile range.

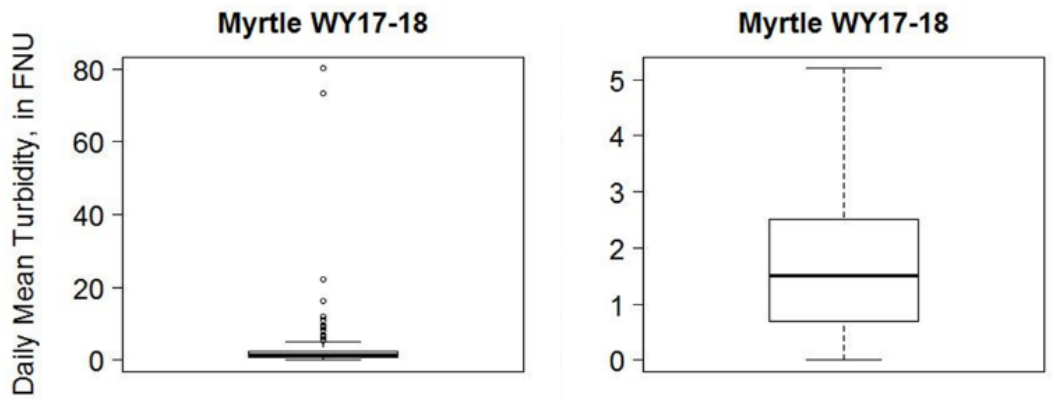

Figure 17. Turbidity box plots for Myrtle Brook monitoring stations for the period of October 1, 2016 – September 30, 2018. The left plot is for the full range of mean daily mean turbidity values; the right plot is for mean daily turbidity values in the lower quantile range.

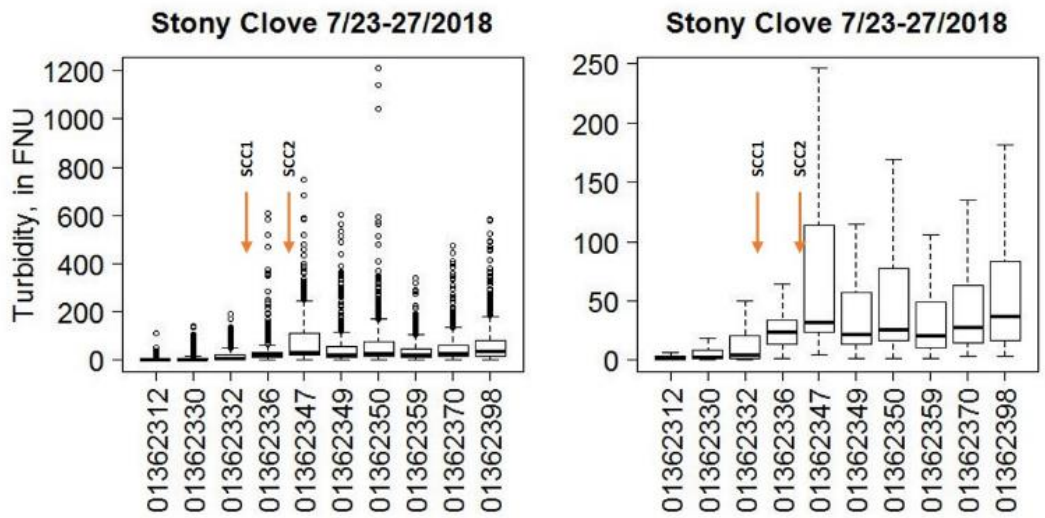

Figure 18. Turbidity box plots for SCC monitoring stations for July 23-27, 2018. Peak discharge at the 01362336 station was 1280 cfs and 1460 cfs at the downstream station 01362370. The left plot is for the full range of mean daily mean turbidity values; the right plot is for mean daily turbidity values in the lower quartile range. Arrows with labels indicate location of monitored reaches with potential future STRPs.

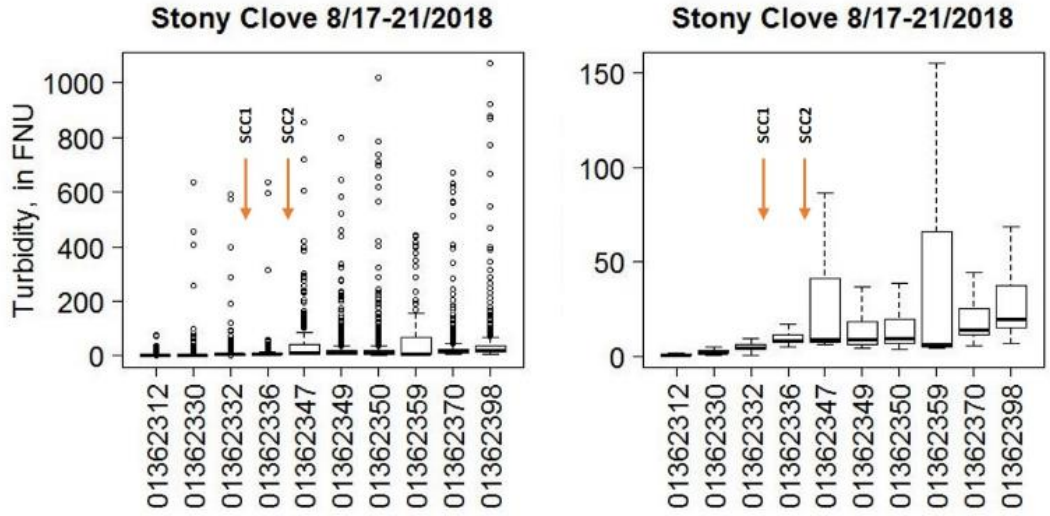

Figure 19. Turbidity box plots for SCC monitoring stations for August 17-21, 2018. Peak discharge at the 01362336 station was 861 cfs and 2650 cfs at the downstream station 01362370. The left plot is for the full range of mean daily mean turbidity values; the right plot is for mean daily turbidity values in the lower quartile range. Arrows with labels indicate location of monitored reaches with potential future STRPs.

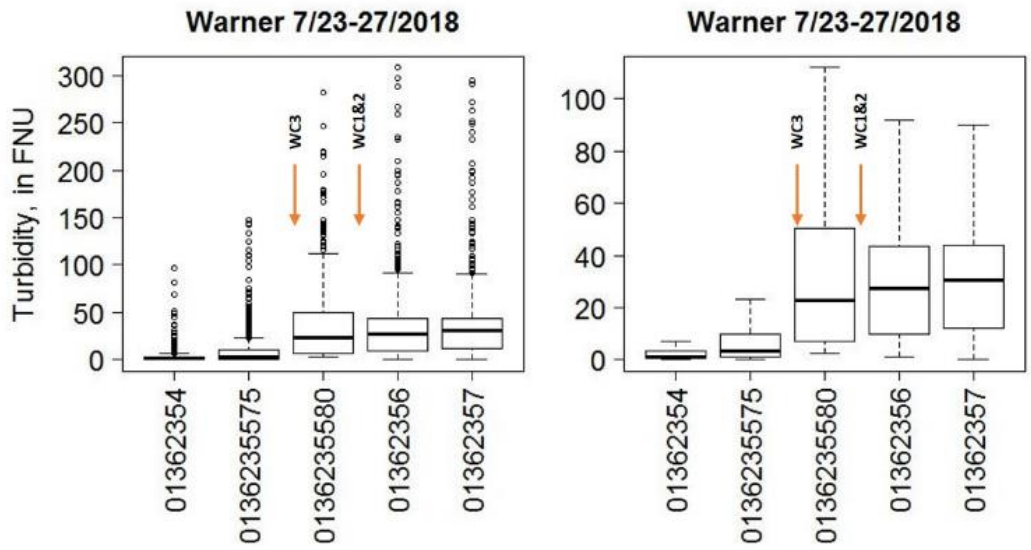

Figure 20. Turbidity box plots for Warner Creek monitoring stations for July 23-27, 2018. Peak discharge at the 01362357 station was 358 cfs. The left plot is for the full range of mean daily mean turbidity values; the right plot is for mean daily turbidity values in the lower quartile range. Arrows with labels indicate location of monitored reaches with potential future STRPs.

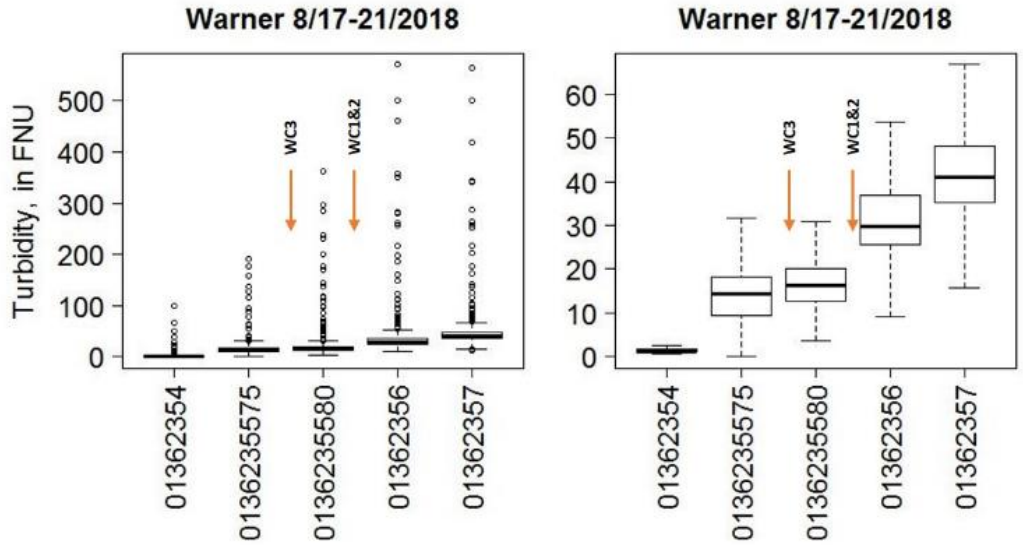

Figure 21. Turbidity box plots for Warner Creek monitoring stations for August 17-21, 2018. Peak discharge at the 01362357 station was 473 cfs. The left plot is for the full range of mean daily mean turbidity values; the right plot is for mean daily turbidity values in the lower quartile range. Arrows with labels indicate location of monitored reaches with potential future STRPs.

Geomorphic/Geologic Data

This report does not include a detailed analysis of the geomorphic and geologic assessment beyond briefly referencing what has been done to date to help identify potential STRP sites. DEP intends to provide a more comprehensive status report of the entire research project in the first biennial FAD deliverable due on March 31, 2019.

DEP has investigated the fluvial geomorphology and geologic sources of turbidity since at least 2000 as part of the comprehensive assessments completed to inform the Stony Clove Creek Stream Management Plan completed in 2005. Assessments included the 2001 baseline SFI mapping of erosional sediment sources and establishing a first set of 27 BEMS, most of which were resurveyed in 2012.

From 2010-2012, DEP completed repeat SFI mapping of WC identifying several reaches that had extensive erosional contact with geologic turbidity sources. Ulster County SWCD completed a repeat SFI mapping of erosional sediment sources on SCC in 2013 and engineering consultants Milone and MacBroom, Inc (MMI) completed a first round of SFI mapping of OCC, HTB and MB. DEP completed a third round of SFI mapping of SCC in 2018.

In 2016, DEP tasked MMI with establishing a revised BEMS study that investigates fewer sites but expands monitoring to cover reach scale channel response with repeat topographic surveying using ground-based total station surveys and high resolution ortho-photogrammetry using drone-mounted cameras. Work also included sediment grain-size analysis of eroding bank sediment and developing hydraulic models for some of the sites. This work is ongoing and will continue through the course of the 10-year research project.

Table 3 provides summary statistics of the SFI mapping in the Stony Clove watershed that DEP used to help interpret turbidity source conditions and select eight turbidity source sites for detailed topographic monitoring and sediment sampling with the understanding that they would be eligible for STRP treatment if the water quality monitoring showed them to be substantial sources. These eight sites are the new BEMS for the current research project. Table 4 summarizes the conditions and level of assessment at each site. Three of the five STRP priority water quality monitoring reaches identified above have current BEMS sites.

Recent suspended sediment fingerprinting completed by USGS in both SCC and Woodland Creek has supported a working assumption that the glacial-related sediment in the watershed is a primary erosional contact source of turbidity. During high magnitude discharge events that mobilize the streambed, re-suspended fine sediment incorporated in the bed accounts for a lot of the turbidity associated with the peak of the flow event. As the peak flow declines and the re-suspension process diminishes, the recent analysis finds that glacial till and glacial lake sediment become the dominant source of suspended sediment causing turbidity. Successful STRP implementation would include removing the stream channel from erosional contact with glacial-related sediment.

Based on the available geomorphic and geologic data we can make the following observations of turbidity source conditions for each of the six prioritized water quality monitoring reaches.

SC-WQM-08: The observed increase in DMT for water years 2017 and 2018, and storm event turbidity values associated with this reach are consistent with observed and monitored geomorphic and geologic conditions in the reach. The 2001, 2013 and 2018 SFI efforts mapped extensive and temporally variable erosional contact with glacial lake sediment in the stream bed and streambanks for a section of stream approximately 1500-3000 feet upstream of station 01362336 at Jansen Road bridge. This section of stream is one of the current BEMS sites (SC-BEMS-03). This is an actively eroding section and STRP treatment at this location would presumably reduce turbidity during storm events.

SC-WQM-07: The observed significant increase in DMT for water years 2017 and 2018, and storm event turbidity values associated with this monitored reach, are not entirely consistent with observed geomorphic and geologic conditions in the reach. The 2001, 2013 and 2018 SFI efforts mapped intermittent and temporally variable erosional contact with glacial lake sediment and glacial till in the stream bed and streambanks for this monitored reach, but the extents of erosional exposure are not consistent with the observed high levels of turbidity at station 01362347. USGS advises there are two potential issues with the turbidity probe at this station: (1) the probe calibration for the recent water year is not complete, and (2) probe placement in a plunge pool below a constructed boulder step may be affected by air bubbles and "churning" of organics. USGS will complete calibration as soon as possible and will investigate the impact of probe placement on measured turbidity. Assuming that there is an actual increase in turbidity through this reach an STRP is likely to produce a measurable reduction in turbidity. Further geomorphic investigation is needed to identify the extent of a potential STRP in this reach.

SC-WQM-05: The observed increase in DMT for water years 2017 and 2018, and inconsistent storm event turbidity values associated with this monitored reach, appear to be associated with the ongoing mass wasting of the left hillslope adjacent to an STRP constructed in 2015 (Stony Clove Creek at Stony Clove Lane). Observations during rainfall events, freeze-thaw events and runoff events have shown that the turbidity plume associated with the untreated mass wasting slope of glacial till and glacial lake sediment is still concentrated on the left side of the channel when it encounters the turbidity probe placed on the left side of the Stony Clove Lane bridge. Probe placement at this location was based on the lack of good downstream placement options and the presence of a pool in the left part of the channel. The 2018 SFI efforts mapped intermittent erosional suspended sediment source exposures through this reach, yet they are not extensive enough to account for the recorded turbidity conditions. Therefore, DEP does not recommend a STRP for this monitoring reach at this time.

WC-WQM-04: The observed increase in DMT for water years 2017 and 2018, and storm event turbidity values associated with this reach are consistent with observed and monitored geomorphic and geologic conditions in the reach. The 2010-2015 SFI efforts mapped a consistently active erosional contact with glacial lake sediment in a stream erosion triggered mass failure for a section of stream approximately 1500 feet upstream of station 0136235580.

This section of stream is one of the current BEMS sites (WC-BEMS-03). This is an actively eroding section and STRP treatment would presumably reduce turbidity during storm events. There are additional smaller turbidity sources mapped in this reach but observations during storm runoff events demonstrate that this site is typically the upstream turbidity source in WC.

WC-WQM-03: The observed minor-to-moderate increase in DMT for water years 2017 and 2018, and storm event turbidity values associated with this reach are consistent with observed and monitored geomorphic and geologic conditions in the reach. The 2001–2015 SFI efforts mapped two sections of stream with consistent erosional contact with glacial lake sediment in the stream bed and streambanks. These two sections of stream are two of the current BEMS sites (WC-BEMS-01 and WC-BEMS-02). Each of these sites have been actively eroding since at least 2010 and are not trending toward stable conditions. STRP treatment at these two locations would presumably reduce turbidity during storm events.

WC-WQM-02: The observed increase in DMT for water years 2017 and 2018, and storm event turbidity values associated with this short reach are not consistent with observed and monitored geomorphic and geologic conditions in the reach. The 2010–2012 SFI efforts mapped extensive erosional contact with glacial lake sediment in the stream bed and streambanks for a section of stream approximately 500 feet downstream of station 01362356 at Silver Hollow Road bridge. This section of stream was removed from the erosional sources with the implementation of the "Warner Creek Site 5" STRP constructed in 2013. Repeated project monitoring surveys and assessments and a recent 2018 visual inspection did not locate erosional contacts with turbidity source material. Further investigation is needed to account for the recent persistent increases in turbidity through this monitored reach.

Based on the available water quality monitoring data and observed geologic and geomorphic conditions, DEP nominates the following priority STRP sites, with the first three sites representing highest priority and the latter two sites representing alternates:

- SCC1: A known section of stream in reach SC-WQM-08 currently mapped as a substantial reach-scale turbidity source that is one of the bank erosion monitoring sites (SC-BEMS-03).
- WC1: A known site in reach WC-WQM-03 currently mapped as a substantial site-scale turbidity source that is one of the bank erosion monitoring sites (WC-BEMS-01).
- WC2: A known site in reach WC-WQM-03 currently mapped as a substantial site-scale turbidity source that is one of the bank erosion monitoring sites (WC-BEMS-02).
- WC3: A known site in reach WC-WQM-04 currently mapped as a substantial site-scale source that is one of the bank erosion monitoring sites (WC-BEMS-03). This site is located on State-owned land and STRP implementation is subject to State approval. Thus, this site is proposed as an alternate reach until site availability is determined.
- SCC2: A yet undefined section of stream in reach SC-WQM-07. The provisional water quality monitoring data indicates turbidity production through this monitored reach. Further analysis by USGS of potential issues with the turbidity probe is required to verify actual turbidity production through this reach. Thus, this site is proposed as an alternate reach for SCC1 if further investigation supports potential implementation, if needed.

4. Conclusion and Recommendations

Based on the preliminary and provisional water quality monitoring data and field assessments to date, DEP recommends advancing the following three sites for design and construction by 2021 to support the study objectives: WC1, WC2, and SCC1. Two alternate sites, WC3 and SCC2, are identified for potential advancement should they be needed. Next steps include seeking authorization to work on State land for WC3, and further investigation at SCC2 to identify the specific conditions and extents requiring treatment. DEP and USGS will continue to collect, analyze and interpret water quality data at all monitoring stations and perform repeat geomorphic assessments to keep track of turbidity and suspended sediment source dynamics in the Stony Clove watershed.

Table 1. Stony Clove Watershed USGS Monitoring Stations

Site Name	Station ID	Station Type	Measure
Stony Clove Creek Blw Ox Clove At Chichester Ny	01362370	Primary	Q, SSC, SSL, T
Stony Clove Creek At Phoenicia Ny	01362398	Secondary	T (est: Q, SSC, SSL)
Stony Clove Creek At Silver Hollow Rd	01362359	Secondary	T (est: Q, SSC, SSL)
Stony Clove Creek At Stoney Clove Lane	01362350	Secondary	T (est: Q, SSC, SSL)
Stony Clove Creek Abv Moggre Rd Nr Chichester Ny	01362349	Secondary	T (est: Q, SSC, SSL)
Stony Clove Creek At Lanesville Ny	01362347	Secondary	T (est: Q, SSC, SSL)
Stony Clove Creek At Jansen Rd	01362336	Primary	Q, SSC, SSL, T
Stony Clove Creek At Wright Rd	01362332	Secondary	T (est: Q, SSC, SSL)
Stony Clove Creek Abv Wright Rd	01362330	Secondary	T (est: Q, SSC, SSL)
Stony Clove Creek At Edgewood Ny	01362312	Secondary	T (est: Q, SSC, SSL)
Ox Clove Abv Mouth @ Chichester Ny	01362368a	Primary	Q
Ox Clove Abv Mouth @ Chichester Ny	01362368b	Primary	SSC, SSL, T
Ox Clove @ Chichester Ny	01362365	Secondary	T (est: Q, SSC, SSL)
Warner Creek Nr Chichester Ny	01362357	Primary	Q, SSC, SSL, T
Warner Creek At Silver Hollow Rd Bridge	01362356	Secondary	T (est: Q, SSC, SSL)
Warner Creek In Silver Hollow Nr Chichester Ny	0136235580	Secondary	T (est: Q, SSC, SSL)
Warner Creek Nr Carl Mountain Nr Chichester Ny	0136235575	Secondary	T (est: Q, SSC, SSL)
Warner Creek Blw Silver Hollow Notch Nr Edgewood	01362354	Secondary	T (est: Q, SSC, SSL)
Hollow Tree Brook At Rt 214 At Lanesville Ny	01362345	Primary	SSC, SSL, T (est: Q)
Hollow Tree Brook At Lanesville	01362342	Secondary	Q, T
Myrtle Brook Abv Mouth @ Rt 214 @ Edgewood Ny	01362322	Primary	Q, SSC, SSL, T

Table 2. Stony Clove Watershed Water Quality Monitoring Delineated Stream Reaches

Reach Name	DS Station[1]	US Station[1]	Length (ft)[2]
SC-WQM-01	NS	01362398	839
SC-WQM-02	01362398	01362370	8854
SC-WQM-03	01362370	01362359	3589
Sc-WQM-04	01362359	01362350	3873
SC-WQM-05	01362350	01362349	4001
SC-WQM-06	01362349	01362347	4120
SC-WQM-07	01362347	01362336	3893
SC-WQM-08	01362336	01362332	5418
SC-WQM-09	01362332	01362330	1609
SC-WQM-10	01362330	01362312	9498
SC-WQM-11	01362312	NS	8764
WC-WQM-01	NS	01362357	2822
WC-WQM-02	01362357	01362356	976
WC-WQM-03	01362356	0136235580	4618
WC-WQM-04	0136235580	0136235575	2099
WC-WQM-05	0136235575	01362354	22793
WC-WQM-06	01362354	NS	16836
OC-WQM-01	NS	01362368	1104
OC-WQM-02	01362368	01362365	3320
OC-WQM-03	01362365	NS	2271
HTB-WQM-01	NS	01362345	405
HTB-WQM-02	01362345	01362342	5807
HTB-WQM-03	01362342	NS	1472
MB-WQM-01	NS	01362322	182
MB-WQM-02	01362322	NS	4099

[1] By default, the first and last water quality-delineated reaches for each stream are only delineated by one station.

[2] Reach length is limited to the extent of stream assessed by SFI mapping and is either measured as the distance between monitoring stations, the distance from the stream confluence to the first monitoring station, or the distance from the last monitoring station upstream to the extent of SFI mapped stream.

Table 3. Status of Stony Clove Creek Watershed SFI and Suspended Sediment/Turbidity Source Characterization. Data is from SFI efforts from 2010–2015.

Stream Name	SFI Reach length (m)	Bank Erosion Length (m)	% Bank Erosion	% Erosional Contact AL	% Erosional Contact N-AL	% Erosional Contact LS	% Erosional Contact GT	% Erosional Contact Mix LS/GT/Al
Stony Clove Creek	16,599	3,697	11%	48%	52%	21%	23%	9%
Ox Clove Creek	2,041	354	9%	70%	30%	14%	16%	0%
Warner Creek	15,284	3,370	11%	82%	17%	6%	11%	0%
Hollow Tree Brook	2,342	466	10%	89%	11%	0%	11%	0%
Myrtle Brook	1,305	326	13%	100%	0%	0%	0%	0%
TOTALS	37,570	8,213	11%	67.4%	32.4%	12%	16%	4%

AL = Alluvium; N-AL = Non-Alluvium; LS = Glaciolacustrine sediment; GT = Glacial Till sediment; Mix = either a colluvial mixing of AL and N-AL sediments or stratified deposits of multiple sedimentologic units.

Table 4. Stony Clove Watershed BEMS status table

Stream	Site	Started	Surveys	Sediment Analysis[1]	Hydraulic Modeling[2]	Description
SCC	SC-BEMS-01	2017	1	Yes	FEMA	Mass wasting of glacial till with alluvium in mountainside. Stream contact is with a colluvial mixture of glacial till and alluvium.
SCC	SC-BEMS-02	2017	1	No	FEMA	Hydraulic erosion and mass wasting of glacial till and alluvium in a high terrace.
SCC	SC-BEMS-03	2018	1	No	FEMA	Hydraulic erosion and mass wasting of glacial lacustrine sediment and alluvium in a high terrace with some lacustrine sediment exposed in stream bed.
WC	WC-BEMS-01	2016	4	Yes	BEMS	Hydraulic erosion and mass wasting of glacial lacustrine sediment and alluvium in high terrace with some glacial lacustrine sediment exposed in stream bed.
WC	WC-BEMS-02	2016	4	Yes	BEMS	Hydraulic erosion and mass wasting of glacial lacustrine sediment and alluvium in low to high terrace at stream avulsion with some glacial lacustrine sediment exposed in stream bed.
WC	WC-BEMS-03	2016	2	Yes	BEMS	Mass wasting of glacial till and glacial lacustrine sediment in mountainside.
OCC	OC-BEMS-01	2016	2	Yes	None	Mass wasting of glacial till in high terrace.
OCC	OC-BEMS-02	2017	1	Yes	None	Hydraulic erosion and mass wasting of glacial till and glacial lacustrine sediment in high terrace.

[1] Sediment grain-size distribution analyses were completed for several sites to get representative ranges of fine sediment content (clay-silt) in the sedimentologic units of alluvium, glacial till, lacustrine sediment and colluvium.

[2] All sites except for the two Ox Clove sites have HEC-RAS models available for hydraulic analysis. MMI has developed dynamic models for sediment transport and storm event analysis using updated topographic data for the 3 Warner Creek sites. Modeling will continue to progress for all sites in 2019.