5. EIS METHODOLOGY

This section describes the methodology that was applied to each technical area assessment to compare the future without and with the Proposed Action. To form the basis of assessments in the EIS, modeling was used to predict the potential differences between the future without the Proposed Action (no IRP: no use of the Ashokan Release Channel and no dredging) and future with the Proposed Action (IRP: use of Ashokan Release Channel in accordance with the Interim Ashokan Release Protocol and delay of dredging). Specifically, modeling was used to estimate differences between the future without and with the Proposed Action that would occur in flow regime and water quality along lower Esopus Creek, and in alum application to water in the Catskill Aqueduct upstream of Kensico Reservoir.

A discussion of OST modeling methodology used to evaluate future operational conditions in the water supply system is provided in Section 5.1, “Operations Support Tool Modeling of Ashokan Reservoir Operations.” Section 5.2, “Lower Esopus Creek Modeling Methodology” describes the methodology used for modeling conditions within lower Esopus Creek. Finally, Section 5.3, “Impact Assessment Methodology” includes a discussion of technical areas that screen from assessment and the methodology used to assess potential benefits and impacts of the future with the Proposed Action as compared to the future without the Proposed Action for each of the remaining technical areas evaluated for the lower Esopus Creek study area and Kensico Reservoir study area.

5.1 OPERATIONS SUPPORT TOOL MODELING OF ASHOKAN RESERVOIR OPERATIONS

As discussed in Section 1.3.4, “Operations Support Tool,” DEP’s Operation Support Tool (OST) is a reservoir system model with embedded reservoir water quality models to support decision-making on how to balance water system objectives (i.e., DEP water supply needs and release requirements). OST uses environmental conditions, reservoir details, and operating constraints to simulate reservoir operations throughout the system, including those at Ashokan Reservoir.[1] OST was used to determine how operation of Ashokan Reservoir in the future with the Proposed Action would affect DEP’s water supply operations and the volume, duration, and water quality of flows (i.e., spills and releases from Ashokan Reservoir) to lower Esopus Creek.

The use of OST in this EIS is consistent with the recommendations in the National Academy of Science's *Review of the New York City Department of Environmental Protection Operations Support Tool for Water Supply* (2018). The National Academy of Science recommended: (1) that the EIS clearly and explicitly outline how OST output will be used as part of the methods, inputs, analyses, and quantification for each impact area; (2) that the historical data used as input to OST for the EIS analysis include the most recent data available, not just through 2013; and (3) consideration of creating simulated streamflow inputs to OST that might reflect climate change. This EIS responded to these recommendations by: (1) describing how OST was used to support the technical area assessments in three locations within the EIS in this section, as well as Section 1.3.4, “Operations Support Tool,” and Section 5.3.14, “Greenhouse Gas Emissions and Climate Change;” (2) extending the hydrological record to include available data

[1] Relevant reservoir details modeled by OST include storage/elevation curves, spillway rating curves, aqueduct capacities, valving configurations, etc.

through 2017[2]; and (3) evaluating a wide range of hydrological conditions, which consider climate change, as described in Section 5.2.1, "Analysis Approach."

Assumptions used in OST are shown in **Table 5.1-1**.

Table 5.1-1. OST Model Assumptions for the EIS

Parameter	OST Settings / Assumptions
Period of Record	10/1/1948 – 9/29/2017
Delaware System Release Protocol	Flexible Flow Management Plan 2017
Ashokan Reservoir Release Protocol	September 2013 Interim Ashokan Release Protocol
Flows	
Rondout West Branch Tunnel Flow	Maximum flow varies depending on operation of Shaft 4
Catskill Aqueduct Diversion	Maximum 595 MGD Minimum 25 MGD, maximum 250 MGD with stop shutters installed
Croton Water Filtration Plant Flow Range	60 to 290 MGD
Ashokan Release Channel Flow	Up to 600 MGD (928 cfs)
Water Quality	
Turbidity Level Regression	Based on inflow to Ashokan Reservoir
Water Quality Models	Schoharie, Ashokan, Kensico, and Rondout Reservoir W2
Ashokan Diversion Turbidity Level Triggers	4 NTU (minimize diversions) 8 NTU (initiate use of Shaft 4 or stop shutters)
Alum Application Trigger Level	2,400 MGD*NTU

[2]At the time that the EIS analyses were conducted the hydrologic record for OST was updated through September 30, 2017 based on the latest approved USGS stream gage data available.

5.2 LOWER ESOPUS CREEK MODELING METHODOLOGY

With respect to lower Esopus Creek, OST only provides information on flows (in the form of spills or releases) leaving Ashokan Reservoir and associated turbidity levels.[3] The OST does not simulate natural background flows or water quality along lower Esopus Creek (i.e., streamflow characteristics that are independent of Ashokan Reservoir flows). To evaluate how flows from Ashokan Reservoir combine with background streamflow, available data from gages along lower Esopus Creek were combined with OST-modeled flows out of Ashokan Reservoir. In addition, while OST simulates the conveyance of flows between reservoirs and downstream of reservoirs, it does not model the hydraulics of those flows (i.e., water depth, flow velocity) through natural or man-made channels. Therefore, a U.S. Army Corps of Engineers (USACE) Hydrologic Engineering Center River Analysis System (HEC-RAS) model was developed for lower Esopus Creek to simulate the hydraulic characteristics of streamflow through lower Esopus Creek. The following sections describe the methodology for each of these items in more detail. Data sources used to describe baseline conditions and inputs to OST are also presented in this section.

5.2.1 ANALYSIS APPROACH

Potential operation of Ashokan Reservoir in the future with the Proposed Action would be influenced by the dynamic hydrologic conditions that would occur in the region as described in Section 7.1, "Water Resources and Water Quality." Hydrologic conditions vary based on season, storm events, and climatic conditions (i.e., periods of high or low inflow to the Reservoir). As a result, hydrology of the region varies from year to year, ranging from very wet to very dry. Furthermore, the Proposed Action would need to operate under a range of future conditions, unlike a more traditional action for which analyses are limited to a specific time period. Therefore, to provide a comprehensive understanding of the benefits and impacts in the future without and with the Proposed Action, a range of hydrologic conditions that could be reasonably expected to occur were evaluated for each technical area assessment.

BINNED ANALYSIS

To capture the effect of various types of inflow conditions, hydrologic condition years were developed for both observed and modeled data in the following manner for a given data set:

- The wettest 25th percentile of years (wet years);
- The driest 25th percentile of years (dry years); and
- The middle 50th percentile of years (normal years).

Metrics for baseline conditions and the future without and with the Proposed Action were calculated and compared using these wet, normal, and dry year definitions. These bins were evaluated to establish summary statistics based on daily conditions. The difference in these metrics between the future without and with the Proposed Action were used to inform each technical area assessment and considered potential differences related to the magnitude, frequency, duration, and seasonality of flows and water quality from Ashokan Reservoir. In addition, binned years were annualized by calculating average monthly conditions across each bin (i.e., flow, water quality) for wet, normal, and dry years to show seasonal patterns.

[3] For the purposes of the EIS, flow and streamflow each refer to the volumetric flow rate of water from Ashokan Reservoir and within lower Esopus Creek, respectively. Specifically, flow and streamflow in this EIS are measured in million gallons per day (MGD) and also in cubic feet per second (cfs).

FULL RECORD ANALYSIS

Full record analyses were also conducted to provide an understanding of the magnitude, frequency, and duration of flow and turbidity over the full record of interest (i.e., OST simulation period). This includes periods of episodic turbidity described in Section 1.2.2, "Operation of the Catskill Water Supply System." As with the binned analyses, summary statistics were developed based on daily conditions. The differences in these summary statistics between the future without and with the Proposed Action were evaluated and used to inform assessments for each technical area assessment.

CLIMATE CHANGE CONSIDERATIONS

DEP has been conducting climate change studies for the last 13 years. DEP has developed and applied integrated climate, watershed, reservoir, and system operations models to evaluate the potential impact of climate change on the City's water supply system. The findings of these studies show that climate change may result in annual average air temperature to increase by 2.0°C, and precipitation by five percent by mid-century. Significant trends in several climate indices, e.g., number of frost days, snowpack, and extreme rainfall events are also projected. Approximately a 20 percent reduction in snowfall and 50 percent reduction in snowpack (March 15) is expected in the watershed. Under these climate conditions, mean annual inflow to the Catskill System is expected to increase by six percent, with greater increases (approximately 25 percent) during December-February and a reduction (approximately 10 percent) during April-June, lessening the overall seasonal variability of inflow. The annual average temperature of Schoharie Creek and Esopus Creek could rise by 1.4°C with a lesser increase (1°C) in temperature for flow through the Shandaken Tunnel. Although annual average turbidity levels in Schoharie and Esopus Creeks are projected to increase by less than 1 NTU, extreme levels of turbidities could increase by more than 50 percent and such high turbidity events could be more frequent in the future. In addition, climate change may result in a 23 percent increase in alum days per year in the future. Overall, DEP's climate change studies demonstrate the high resiliency, high reliability, and low vulnerability of City's water supply system with a minimal effect on water quality within the system.

In addition to reviewing DEP's climate change studies, an investigation of observed streamflow was conducted to further consider potential effects of climate change on streamflow. Observed streamflow at the U.S. Geological Survey (USGS) gage at Coldbrook, NY over the last 30 years was evaluated and compared to observed streamflow for the wet, normal, and dry years over the OST period of record. Observed streamflow over the past 30 years was found to be similar to observed streamflow for the middle 50th percentile of years or 'normal years' of the OST period of record (see **Figure 5.2-1**).

Mean annual precipitation projections were also evaluated using a USGS tool[4] that predicts this information for a given watershed based on multiple climate models. For the Esopus Creek watershed, mean annual precipitation is projected to be 58 to 60 inches by the end of the century, using the tool's Representative Concentration Pathway (RCP) 4.5 (low) and RCP 8.5 (high) emissions scenario (**Table 5.2-1**). The year 2100 was selected for analysis since it is the latest future year available at this time and represents the greatest projected increase in mean annual precipitation in the tool. When compared with historical annual precipitation over the OST period of record from 1948 to 2017, this projected amount is similar to mean annual precipitation for the wettest 25th percentile of years or 'wet years' as described above. In the future, there will be an opportunity to revisit the Ashokan Reservoir's Revised Operating Protocol, as needed, to understand how seasonal shifts in precipitation from climate change may affect the operation of Ashokan Reservoir.

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[4] This USGS tool is available online at https://ny.water.usgs.gov/maps/floodfreq-climate/.

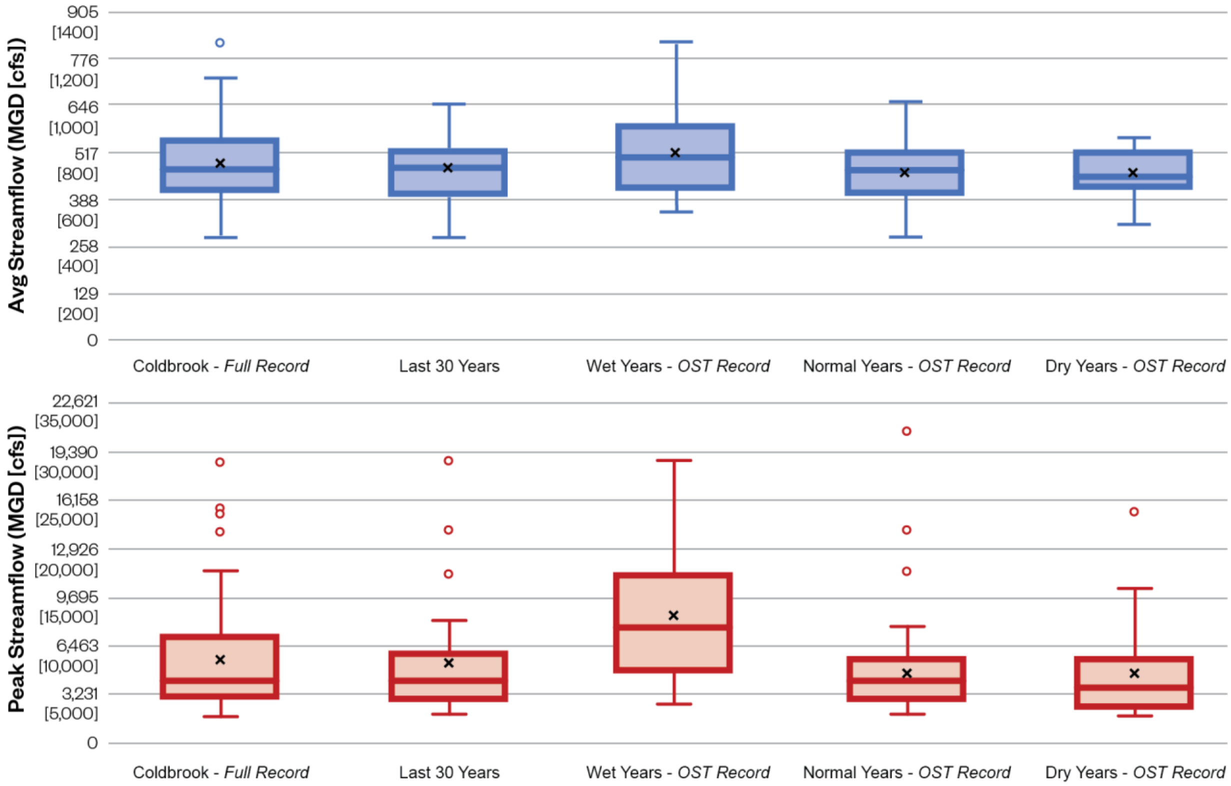

Figure 5.2-1. Observed Streamflow at the Coldbrook Gage (USGS 013625000) Over the Period of Record, For the Last 30 Years, and for Wet, Normal, and Dry Years

Table 5.2-1. Emissions Scenarios Considered for the EIS

USGS Emissions Scenario	Definition	Mean Annual Precipitation (inches)	Year
RCP 4.5	Low Emissions Scenario	58	2100
RCP 8.5	High Emissions Scenario	60	

Note:
RCP denotes the Representative Concentration Pathway

5.2.2 ANALYSIS CONDITIONS FOR LOWER ESOPUS CREEK

Future hydrologic conditions were predicted through modeling, based on conditions observed over the past 69 years of hydrologic records. Where available, observed data were analyzed to supplement and "ground truth" analysis of future conditions with and without the Proposed Action.

OBSERVED DATA

Observed data are presented within the EIS to establish baseline conditions either prior to or following implementation of the IRP. Observed data were also used, where appropriate, to illustrate potential conditions that could occur in lower Esopus Creek in the future without and with the Proposed Action (e.g., streamflow at certain locations). Flows from Ashokan Reservoir were measured by DEP. Streamflow within lower Esopus Creek was primarily measured by the USGS gage located at Mount Marion (USGS Gage No. 01364500). This gage is the main source of streamflow data within lower Esopus Creek, beginning in 1970. This gage also started recording turbidity data for lower Esopus Creek in 2013. The Mount Marion gage measures combined streamflow within lower Esopus Creek, comprised of any flows from Ashokan Reservoir and streamflow within lower Esopus Creek upstream of the gage.[5] Pursuant to the Consent Order, another lower Esopus Creek stream gage was installed at Lomontville (USGS Gage No. 01363556). Flow data for this location were only available beginning in November 2013, with turbidity data available in 2016. A summary of the observed data used within the EIS analyses is presented in **Table 5.2-2**. This includes weekly grab sample data from the Ashokan Release Channel and spillway, when releases and/or spills are occurring, and weekly grab sample data at the spillway confluence, lower Esopus Creek above Saw Kill, and lower Esopus Creek at Saugerties Beach per the Water Quality Monitoring Plan incorporated into the IRP. Analytes sampled in flows leaving Ashokan Reservoir and streamflow in lower Esopus Creek include turbidity, temperature, and total suspended solids (TSS).

[5] The Mount Marion USGS gage has a total drainage area of 419 square miles, but because of the hydraulic disconnect from the construction of Ashokan Reservoir, the natural drainage area is effectively 164 square miles plus the spills and releases from Ashokan Reservoir.

Table 5.2-2. Observed Lower Esopus Creek Data Sources Used in the EIS

Purpose / Parameter	Location	Data Source	Collection Frequency	Period of Analysis
Pre-IRP flow conditions	Flow from Ashokan Reservoir	DEP spillway and Ashokan Release Channel	Daily (when spilling and/or during releases)	June 1947 through May 2013
	Streamflow within lower Esopus Creek	Mount Marion gage	Every 15 minutes	March 1970 through May 2013
IRP flow conditions[1]	Flow from Ashokan Reservoir	DEP spillway and Ashokan Release Channel	Daily (when spilling and/or during releases)	June 2013 through February 2019
	Streamflow within lower Esopus Creek	Mount Marion gage	Every 15 minutes	June 2013 through December 2019
		Lomontville gage	Every 15 minutes	November 2013 through December 2019
Turbidity Levels	Flow from Ashokan Reservoir	DEP spillway and Ashokan Release Channel	Daily (when spilling and/or during releases)	January 2013 through December 2019
	Lomontville	Lomontville gage	Every 15 minutes	January 2016 through December 2019
	Mount Marion	Mount Marion gage	Every 15 minutes	November 2013 through December 2019
	Saugerties Beach	DEP grab samples	Weekly	January 2011 through December 2019
	Above Saw Kill	DEP grab samples	Weekly	March 2011 through December 2019
	Saw Kill and Plattekill	DEP grab samples	Weekly	September 2013 through December 2019

Table 5.2-2. Observed Lower Esopus Creek Data Sources Used in the EIS (Continued)

Purpose / Parameter	Location	Data Source	Collection Frequency	Period of Record
Total Suspended Solids (TSS)	Flow from Ashokan Reservoir	DEP spillway and Ashokan Release Channel	Daily (when spilling and/or during releases)	January 2013 through December 2019
	Saugerties Beach	DEP grab samples	Weekly	January 2011 through December 2019
	Above Saw Kill	DEP grab samples	Weekly	March 2011 through December 2019
DO	DO within Ashokan Reservoir, Release Channel and Spillway	DEP measurements at Boiceville, Ashokan West basin, Spillway, Release Channel	Periodically	January 2011 through December 2018
	DO within lower Esopus Creek	Above Saw Kill, Saugerties Beach	Periodically	January 2011 through December 2011
pH	pH within Ashokan Reservoir, Release Channel and Spillway	DEP measurements at Boiceville, Ashokan West basin, Spillway, Release Channel	Periodically	January 2011 through December 2018
	pH within lower Esopus Creek	Above Saw Kill, Saugerties Beach	Periodically	January 2011 through December 2011

Table 5.2-2. Observed Lower Esopus Creek Data Sources Used in the EIS (Continued)

<table>
<tr><th>Purpose / Parameter</th><th>Location</th><th>Data Source</th><th>Collection Frequency</th><th>Period of Record</th></tr>
<tr><td>Historical alum application events</td><td>Flow from Ashokan Reservoir</td><td>DEP spillway and Ashokan Release Channel</td><td>Daily (when spilling and/or during releases)</td><td>1981 through 2011</td></tr>
<tr><td rowspan="6">Temperature</td><td>Temperature within Ashokan Reservoir</td><td>DEP release channel and east basin measurements</td><td>Weekly</td><td>July 2011 through December 2018</td></tr>
<tr><td rowspan="5">Temperature within lower Esopus Creek</td><td>DEP measurements at the spillway confluence</td><td>Periodic</td><td>March 2011 through May 2019</td></tr>
<tr><td>DEP measurements Above Saw Kill and at Saugerties Beach</td><td>Weekly</td><td>July 2011 through December 2018</td></tr>
<tr><td>Saw Kill and Plattekill</td><td>Weekly</td><td>2013 through 2016, June through November</td></tr>
<tr><td>NYSDEC data at Hurley</td><td>Daily</td><td>2013 to 2016, June through November</td></tr>
</table>

Notes:

[1] While the IRP was released on September 27, 2013 as part of the Consent Order, IRP flows are evaluated from June of 2013 to capture the full water year when the IRP was implemented. A water year is defined as the flow period between June 1st and May 31st (e.g., Water Year 2016/2017 runs from June 1, 2016 through May 31, 2017), in conformance with the starting period for DEP's reservoirs being full. The Lomontville gage was not operational until November 2013.

[2] The following sites were included in the Water Quality Monitoring Plan incorporated into the IRP: Ashokan Release Channel, Ashokan Spill, lower Esopus Creek Confluence (spillway confluence), lower Esopus Creek at Saugerties Beach, and lower Esopus Creek above Saw Kill.

MODELED DATA

Modeling was used to describe potential differences between the future without and with the Proposed Action for DEP water supply reliability, streamflow and water quality in lower Esopus Creek, and water quality of diversions to Kensico Reservoir. The models used in the EIS relied upon historical records of flow and water quality for Ashokan Reservoir and streamflow and water quality for lower Esopus Creek as shown in **Table 5.2-3**.

Table 5.2-3. Hydrologic Inputs to Lower Esopus Creek Models

Purpose / Parameter	Location	Hydrological Input
Anticipated Spills and Releases	Flow from Ashokan Reservoir	1948 through 2017
Anticipated Streamflow in lower Esopus Creek	Streamflow within lower Esopus Creek (Mount Marion Gage)	1970 through 2017

5.2.3 TOTAL FLOW ESTIMATION

To estimate total lower Esopus Creek streamflow under a range of conditions, background streamflow in lower Esopus Creek was first calculated. To do this, measured Ashokan Reservoir spill and release flow data was subtracted from observed Mount Marion streamflow data for the streamflow period of record at Mount Marion (1971-2017) (Mount Marion period of record).[6] The background streamflow for each day of the Mount Marion streamflow period of record was then scaled to different locations along lower Esopus Creek using the ratio of a location's drainage area to that of Mount Marion. This provided an estimate of background streamflow at various points along lower Esopus Creek on any given day over the Mount Marion period of record. For example, at Lomontville, total streamflow was estimated to be 15 percent of the streamflow recorded at the Mount Marion gage since the sub-watershed area at Lomontville is 15 percent of the total watershed area between the Ashokan Release Channel and Mount Marion.

The same time period was then modeled, using OST, to determine daily flows from Ashokan Reservoir in the future without and with the Proposed Action. Daily flows from Ashokan Reservoir were then added to corresponding daily background streamflow at each point along lower Esopus Creek to estimate total daily streamflow within lower Esopus Creek from 1971 to 2017. Potential differences between total lower Esopus Creek streamflow in the future without and with the Proposed Action were evaluated to assess potential benefits and impacts for each of the technical areas evaluated within the EIS, as described further in Section 5.3, "Impact Assessment Methodology."

5.2.4 HYDROLOGIC ENGINEERING CENTER RIVER ANALYSIS SYSTEM

HEC-RAS is widely used for hydraulic analyses and flood assessments for conveyances ranging from small swales and creeks to large river systems. A HEC-RAS model was developed for lower Esopus Creek to model physical conditions within lower Esopus Creek across a wide range of streamflow that could occur in the future without and with the Proposed Action.

An accurate representation of lower Esopus Creek bathymetry and topography (i.e., geometry) was developed from 47 surveyed cross-sections; nine surveyed bridge structures; 34 cross-sections from a Federal Emergency Management Agency (FEMA) flood model for lower Esopus Creek; and five

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[6] For this EIS, some periods of analysis start and end with complete water years. A water year is defined as the flow period between June 1st and May 31st (e.g., Water Year 2016/2017 runs from June 1, 2016 through May 31, 2017), in conformance with the starting period for DEP's reservoirs being full.

surveyed topographic areas. The surveyed cross-sections/areas were incorporated into a one-meter-resolution Digital Elevation Model (DEM) obtained from the NYS Statewide Digital Orthoimagery Program for Ulster County. Upstream and downstream boundary conditions were established and the model was calibrated based on observed water surface elevation data collected at each surveyed cross-section. Upstream boundary conditions were set near the confluence with Little Beaverkill and downstream boundary conditions were set at Cantine Dam.[7,8] Information from the model was used to evaluate how inundation and velocity of streamflow may benefit or impact each of the technical areas evaluated within the EIS, as described in Section 5.3, "Impact Assessment Methodology."

5.3 IMPACT ASSESSMENT METHODOLOGY

As part of the impact analyses, baseline conditions applicable to each technical area were established by compiling data obtained from a review of desktop information (e.g., hydrologic data, system modeling, maps, plans, aerial imagery, and geospatial data sets), as well as observations made during field assessments conducted between late 2006 and early 2019.

An initial assessment was conducted for each technical area to determine which areas required evaluation in the EIS. The following technical areas did not warrant further impact assessment for both lower Esopus Creek and Kensico Reservoir study areas as described below.

- **Community Facilities and Services**: For both study areas, the Proposed Action would not physically displace or alter a community facility or cause a change in population that may affect services delivered by a community facility.
- **Shadows**: The Proposed Action would not result in new structures or additions to existing structures greater than 50 feet tall or be located adjacent to, or across from, a sunlight-sensitive resource.
- **Solid Waste and Sanitation Services**: The Proposed Action would not result in the new generation of 50 tons per week or more of solid waste.
- **Environmental Justice**: No Potential Environmental Justice (PEJ) areas (minority and low-income communities) are located within either study area.

Provided below is a more detailed discussion of the impact assessment methodologies for the remaining technical areas which may be affected by the Proposed Action at one or both of the study areas.

5.3.1 WATER RESOURCES AND WATER QUALITY

For the lower Esopus Creek assessment, water resources include surface water (e.g., rivers, streams, and reservoirs), floodplains, and groundwater. The physical processes that occur in the geology and land features of lower Esopus Creek are shaped by flowing water and are directly influenced by the hydrology of the region. Therefore, the lower Esopus Creek assessment also included an evaluation of stream geomorphology, which considered how potential differences between streamflow and sediment load in the future without and with the Proposed Action could alter the pattern, profile, and dimension of the lower Esopus Creek channel.

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[7] Boundary conditions are needed to constrain the model at its upstream and downstream extents to account for hydraulic conditions outside of the modeled area. For lower Esopus Creek, the model extends from Cantine Dam upstream to the point that releases enter lower Esopus Creek.

[8] The section of lower Esopus Creek downstream of Cantine Dam is tidally influenced and, therefore, was not included in the HEC-RAS model.

For the Kensico Reservoir assessment, water resources include surface water and floodplains. The water resource analysis in the Kensico Reservoir study area evaluated the physical, chemical, and biological characteristics of water within Kensico Reservoir without and with the Proposed Action.

LOWER ESOPUS CREEK STUDY AREA

The lower Esopus Creek water resources and water quality assessment includes an evaluation of surface water, groundwater, floodplains, erosion and deposition, and water quality.

SURFACE WATER

The Proposed Action, particularly operation of the Ashokan Release Channel in accordance with the IRP, was evaluated for its potential to affect the flow regime,[9] channel geomorphology, and water quality of lower Esopus Creek as compared to the future without the Proposed Action. Baseline streamflow conditions in lower Esopus Creek were established by: (1) conducting a desktop mapping of surface water within the study area; (2) evaluating seasonal streamflow patterns and operations at Ashokan Reservoir for wet, normal, and dry years; (3) developing flow duration curves of streamflow in lower Esopus Creek; and (4) comparing hydrographs within lower Esopus Creek with spills and releases from Ashokan Reservoir. Potential differences in the flow regime of lower Esopus Creek between the future without and with the Proposed Action were evaluated by: (1) combining spills and releases from Ashokan Reservoir with streamflow within lower Esopus Creek, and comparing streamflow during wet, normal, and dry years; (2) comparing seasonal streamflow patterns in lower Esopus Creek for wet, normal, and dry years; (3) comparing flow duration curves for lower Esopus Creek; and (4) comparing hydrographs in lower Esopus Creek.

GROUNDWATER

The groundwater impact assessment consisted of: (1) characterizing aquifers and their potential hydraulic connectivity to surface water along the valleys of upper Esopus Creek and lower Esopus Creek, based on a review of published reports by USGS; and (2) qualitatively describing potential differences in groundwater conditions between the future without and with the Proposed Action.

FLOODPLAINS

The floodplains assessment consisted of: (1) determining flood flow frequencies for baseline conditions following the methodology of USGS Bulletin 17B;[10,11] (2) mapping 100- and 500-year floodplains for baseline conditions; and (3) comparing flood flow frequencies for the future without and with the Proposed Action. The 100-year flood recurrence interval (100-year streamflow event) based on observed streamflow at Mount Marion was also compared to that presented in the 2016 Flood Insurance

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[9] The flow regime of a stream refers to its temporal pattern of high and low streamflow. Flow regimes are commonly characterized by flow magnitude, flow frequency and duration, seasonality of flows, and the relative contributions of surface water runoff and background streamflow. See Section 7.1.1 of this EIS, "Flow Regime and Water Quality in Lower Esopus Creek," for further discussion of flow regime.

[10] USGS Bulletin 17B is a traditional federal method for performing flood frequency analysis in the United States and has been used for numerous unregulated and regulated flood frequency studies since its publication in 1982. USGS 17B methodology uses historical streamflow observations to develop a Log-Pearson Type III distribution for determining flood recurrence intervals (e.g.,100-year, 500-year) at a given location (i.e., Mount Marion gage).

[11] USGS. "Guidelines for Determining Flood Flow Frequency." *Bulletin 17B of the Hydrology Subcommittee*. 1982.

Study (FIS) for Ulster County. Any changes to Flood Insurance Rate Maps (FIRMs) for insurance purposes in the future without or with the Proposed Action would be determined by FEMA and would be distinct from any flooding analysis conducted under this EIS.

EROSION AND DEPOSITION

Potential changes in stream geomorphology between the future without and with the Proposed Action would be related to changes in erosion and deposition within lower Esopus Creek. A number of data collection efforts were undertaken to support geomorphology assessments of erosion and deposition along lower Esopus Creek and are described below in more detail. First, a desktop analysis was completed using aerial photography to estimate relative channel migration throughout lower Esopus Creek. Sites were selected for field data collection using the results of this initial analysis, information about lower Esopus Creek geology and topography presented in a report published by Milone and MacBroom in 2009,[12] and feedback from 2011 surveys of property owners along lower Esopus Creek. The selected cross-sections cover a range of locations in lower Esopus Creek that vary based on their stream characteristics (i.e., geology, stream channel width, bank composition, bank height) and observed changes in the years prior to monitoring. Field data collection efforts at these cross-sections included topographic cross-section surveys, Wolman pebble counts, Bank Assessment for Non-point Source Consequences of Sediment (BANCS) assessments, bank pin measurements, and sediment samples. The general intent of these data collection efforts was to provide information to measure or estimate baseline rates of bank retreat (or deposition where applicable) and determine what, if any, changes may be attributable to potential changes in streamflow in lower Esopus Creek between the future without and with the Proposed Action. These assessments included estimations of bank retreat rates from the BANCS assessments, actual bank pin measurements to estimate bank retreat rates, and consideration of sediment supplies and transport, shear stress, and stream power.

Channel Centerline Migration Analysis

The channel centerline migration analysis was a desktop analysis to determine areas of active lateral channel migration in lower Esopus Creek. Imagery was available in 1994, 2001, 2004, 2009, 2013, and 2016. The aerial images were analyzed using ArcGIS 10.6 to estimate historical channel migration rates between consecutive imagery dates. The general approach to measuring channel centerline migration follows the methodology of Lagasse, et al. (2004).[13] Centerlines were digitized for 19 meanders along lower Esopus Creek based on aerial image quality.[14] These comparisons of channel migration were made in feet per year based on the average migration rates of the stream centerlines themselves; they are not measurements of bank movement and should be used for relative comparisons across meanders or time periods only.

Field Assessments

Seventeen cross-section locations along lower Esopus Creek downstream of the spillway confluence were selected in 2012 for monitoring of stream geomorphic characteristics (**Figure 5.3-1**). The presence of geomorphic characteristics and conditions that can accelerate or resist bank erosion were documented at these 17 cross-sections during field assessments. These factors included particle size, soil composition and properties, the presence or absence of vegetation, bank dimensions, and local hydraulics near the

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[12] Milone & MacBroom. 2009. River Reconnaissance Report for Sustainable River Management: Lower Esopus Creek, Ulster County, NY.

[13] Lagasse, P., L.W. Zevenbergen, W.J. Spitz, C.R. Thorne. 2004. Methodology for Predicting Channel Migration. National Cooperative Highway Research Program Document 67 (Project 24-16).

[14] A meander is a winding curve or bend in a stream that is the result of both erosion and depositional processes.

streambank. Bank sediment composition directly influences resistance to bank erosion. Coarse sediment (ranging from cobbles to boulders) is more resistant to hydraulic shear stress than sand and gravel, whereas cohesive sediment (composed mostly of clay and silt particles) have an increased initial resistance to erosion due to inter-particle forces. The presence of woody vegetation on the surface of a stream bank or in the “riparian” zone helps to hold bank material in place and resist erosion. When riparian vegetation is absent and the bank surface sediment is exposed, resistance to erosion is reduced. Additional factors that were considered during field monitoring (since they can influence erosion through modification of stream channel hydraulics) include: the presence or absence of large wood or debris accumulations that can direct erosive flows toward a stream bank, proximity to the confluence of a tributary that provides flow and sediment contributions, in-stream depositional features such as mid-channel islands or transverse bars that can increase shear stress against a bank, or the presence or absence of bank armoring (e.g., riprap) that increases channel resistance to erosion.

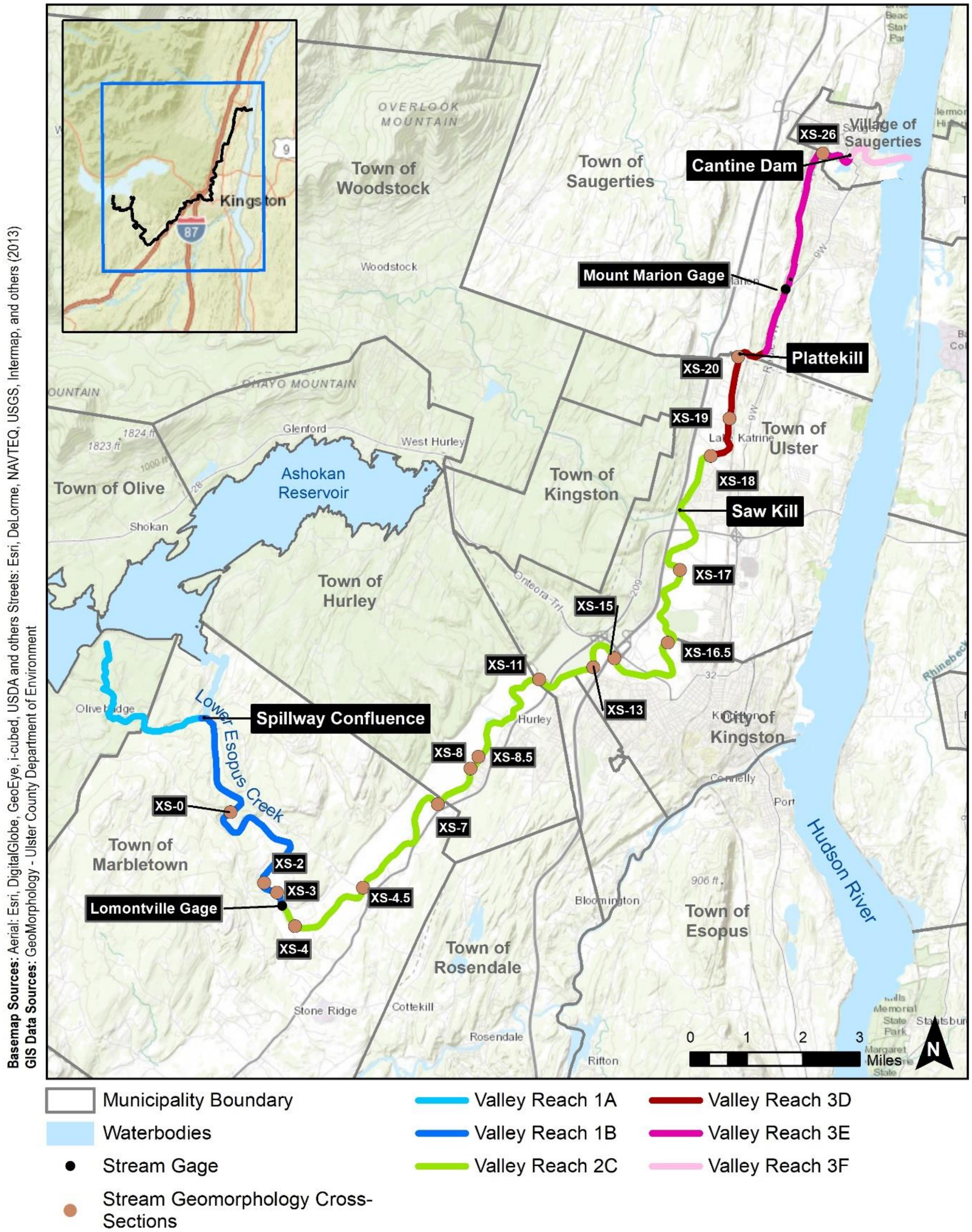

Figure 5.3-1
Lower Esopus Creek Study Area
Stream Geomorphology Cross-Sections

Nine site visits were conducted at these cross-sections over seven years of monitoring, as follows: September 2012, April 2013, October 2014, August 2015, October 2015, March 2016, November 2017, April 2018, and March 2019. Most stream geomorphology cross-sections were established in September 2012, and the remaining ones were established in April 2013. Starting in October 2014, all cross-sections were revisited during each field visit.

A similar geomorphic investigation was conducted in 2006 for the portion of lower Esopus Creek upstream of the spillway confluence. This investigation observed stream features and measured channel dimensions and particle size distributions in lower Esopus Creek between the Ashokan Release Channel and the spillway confluence.

Topographic Cross-Section Surveys

Topographic cross-section surveys were conducted along lower Esopus Creek in 2012 and in 2018 for the dual purpose of creating a detailed surface for the HEC-RAS model and supporting stream geomorphology assessments. Surveys included station and elevation (in feet) of the stream channel bottom and floodplain.

In 2018, five areas were selected for a detailed two-dimensional topographic survey of the stream channel bottom. These detailed topographic areas were surveyed to support the evaluation of complex surface dynamics at areas of concern for potential erosion and/or deposition. An area of approximately 250,000 square feet was surveyed at each location.

Channel-Forming Discharge

A channel-forming discharge (CF discharge) analysis was conducted to evaluate the stability of the lower Esopus Creek channel in the future without and with the Proposed Action. USACE defines CF discharge as "a theoretical discharge that if maintained indefinitely would produce the same channel geometry as the natural long-term hydrograph." For a stable alluvial stream (i.e., streams that have the ability to change their shape and are neither aggrading nor degrading), CF discharge is defined as the representative streamflow that transports the most sediment over time and maintains a stable channel form. Streamflow that begins to mobilize larger size bedload material and cause channel degradation (erosion of the streambed) are those that are at or above the CF discharge. These CF discharge concepts are applicable to stable alluvial streams (Copeland 2000).[15] The conceptual CF discharge was used to represent the streamflow that helps maintain channel stability within lower Esopus Creek. As described below, this was selected rather than other morphologically-defined streamflow, because the hydrology of lower Esopus Creek is regulated due to the presence of Ashokan Reservoir.

Field estimations of CF discharge were conducted at four riffle sections of lower Esopus Creek where measurements were taken specifically to estimate streamflow (cross-sections 0, 2, 7, and 8).[16] Field estimates of CF discharge are based on stream slope, bed material, and stream cross-section. The cross-section dimensions associated with CF discharge in turn must be established through the accurate identification of slope-break field indicators (e.g., top-of-bank) and the determination of which slope-break feature represents the CF discharge.

Figure 5.3-2 is a schematic representation of a typical cross-section of lower Esopus Creek between the Olivebridge Dam and City of Kingston and shows conceptual slope-break (SB) locations. Starting at water's edge, the first slope-break, SB1, represents the first observable change in slope (typically the top of a gravel-cobble bar). This first slope-break typically defines the active low-flow channel, or inner berm. SB2 represents the CF slope-break; on average, and over time, lower Esopus Creek moves the most

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[15] Copeland, R.R. 2000. Channel-Forming Discharge. USACE ERCD/CHL CHETN-VIII-5.

[16] A riffle is a shallow, faster moving section of a stream and is agitated by rocks.

water and sediment when water reaches this level. SB2 is usually recognizable by the presence of a top-of-bank feature (what most people refer to as the “streambank”). This is usually the point at which long-term tree growth (the tree-line) begins. The third SB (SB3) marks the historical channel-forming terrace, if it is present. The long-term presence and operation of Ashokan Reservoir has reduced the magnitude from the historical CF discharge; the Reservoir provides flood storage and attenuates peak streamflow downstream. Therefore, the post-dam CF discharge is substantially less than before the dam was in place. A fourth SB (SB4) is sometimes observed further onto the floodplain and can correspond to infrequent large storms.

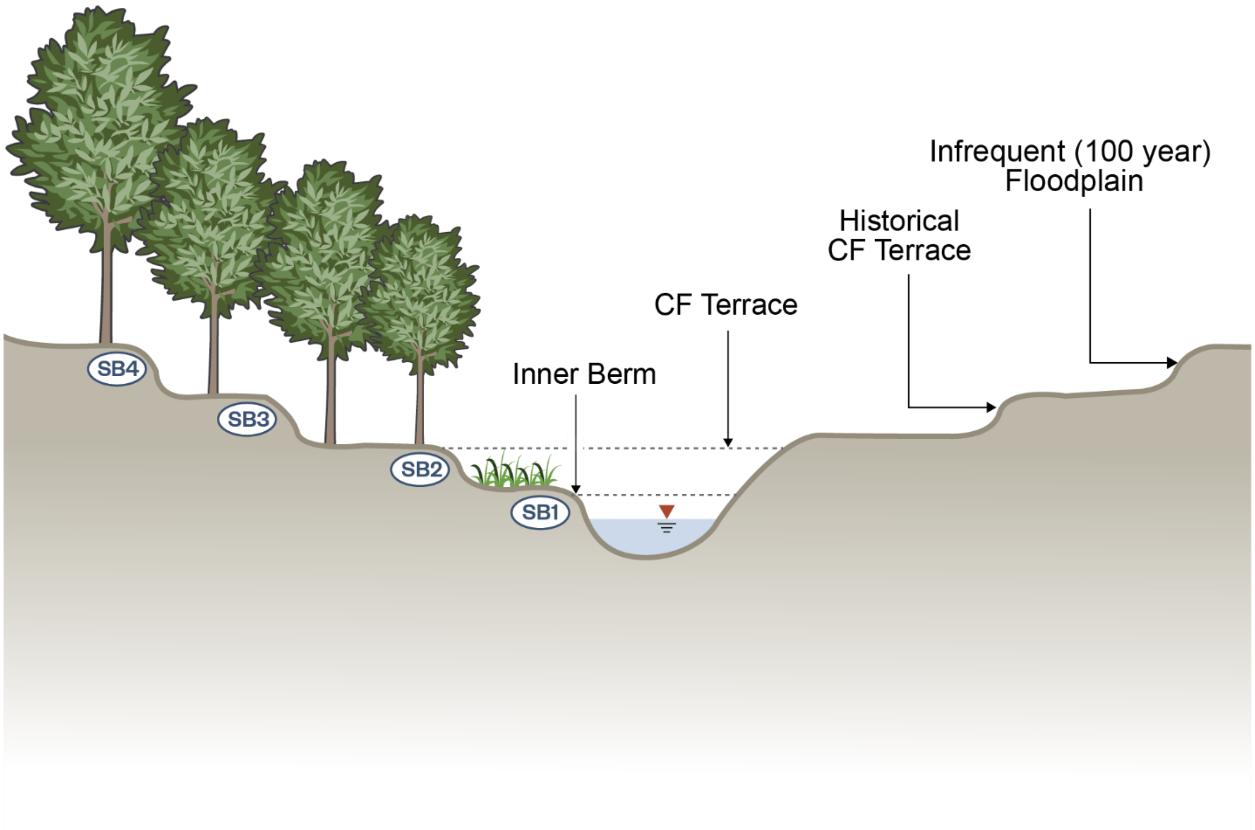

Figure 5.3-2. Typical Stream Valley Slope-Break Features and Channel-forming (CF) Terraces

Slope-breaks within lower Esopus Creek were identified in two ways; first, in the field via on-site investigations, and second through the review of surveyed cross-section data as entered into Rivermorph® software. Fieldwork identified slope-breaks from the water’s edge up each bank at riffle locations until SB2 (the probable CF discharge terrace) could be established. The elevation differences between SBs were sometimes difficult to determine visually; in these cases, surveyed cross-section data were used to help identify the slope-breaks associated with the CF terrace.

To estimate a streamflow rate associated with the CF discharge indicators, additional field measurements of particle size distributions, stream slope, and a cross-sectional area were required. Stream slope was measured at relevant cross-section locations when topographic cross-section surveys were completed. A cross-sectional area at varying water surface elevations was established from dimensions of the topographic cross-sectional surveys. Discharge was then estimated from field data using Manning's equation (Manning 1891).[17]

Regional curves were used to estimate bankfull discharge, which is another method that can be used to estimate CF discharge. Bankfull discharge is typically defined as the maximum discharge that a channel can convey without flowing onto its floodplain. Regional curves are regression equations that relate a field-calibrated bankfull discharge at a streamflow gage and associated bankfull channel characteristics to drainage area, providing estimates of bankfull discharge and channel dimensions at ungaged sites. There are bankfull discharge regional curves, stratified by hydrologic region (Lumia, 1991), available for all of New York State (Mulvihill et al., 2012).[18,19] Lower Esopus Creek is within hydrologic region 4. Bankfull discharge regional curves are not intended to be applied in streams that are substantially regulated by dams, such as the Ashokan Reservoir dam. The hydrologic region 4 regional curve significantly overestimates bankfull discharge for lower Esopus Creek when compared to field estimations from slope-breaks, due to lower Esopus Creek being below a dam, having a drainage area larger than reference stations used to develop the regional curve, and having different valley settings from reference stations (Miller and Davis, 2003). Therefore, bankfull discharge using regional curves was not used to establish the CF discharge in the lower Esopus Creek erosion and deposition assessment. Estimated CF discharge from the field was related to specific recurrence intervals (e.g., the 2-year storm). Note that a specific recurrence interval (RI) discharge should not be used to estimate a CF discharge, but can be compared to CF discharge for consistency. Recurrence intervals were established using streamflow data at the Mount Marion gage and historical spill from Reservoir operations records.

In addition to the CF discharge, the streamflow associated with the inner berm (IB) or active low-flow channel was identified. Low flows such as the average daily streamflow are concentrated within the active low-flow channel. The IB is usually associated with the first observable bar feature and is lower than the "top-of-bank" slope-break defined by the CF discharge; essentially it is a channel within a channel, with a smaller cross-sectional area than the main channel.

<u>Sediment Load Analysis</u>

Potential differences in sediment load in the future without and with the Proposed Action were evaluated based on differences between the frequency of occurrence of certain streamflow within lower Esopus Creek. The assessment also considered how observations of streamflow changes within lower Esopus Creek compared to observed turbidity level and flow data from the Reservoir available since implementation of the IRP.

<u>Bank Assessment for Non-point Source Consequences of Sediment (BANCS)</u>

Use of the Rosgen BANCS model was considered for estimating reach-to-reach streambank erosion. BANCS analyses were conducted to estimate potential differences in bank erosion rates between the future without and with the Proposed Action. They were conducted from 2012 to 2018 at all 17 stream geomorphology cross-sections. BANCS uses methods developed by Rosgen (2009)[20] based on field observations of physical variables (such as bank height, bank angle, root depth, and streambank material

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[17] Manning, R. 1891. On the Flow of Water in Open Channels and Pipes. Transaction of the Institution of Civil Engineers of Ireland 20:161-207.

[18] Lumia, R., 1991. Regionalization of Flood Discharges for Rural, Unregulated Streams in New York, Excluding Long Island. U.S. Geological Survey Water-Resources Investigations Report 90-4197, 119 pp. https://pubs.usgs.gov/wri/1990/4197/report.pdf, accessed 2020.

[19] Mulvihill, C.I. and Baldigo, B.P. 2012, Optimizing Bankfull Discharge and Hydraulic Geometry Relations for Streams in New York State. JAWRA Journal of the American Water Resources Association, 48: 449-463.

[20] Rosgen, D. 2009. Watershed Assessment of River Stability and Sediment Supply (WARSSS). Wildland Hydrology.

composition), hydraulic stress in the near-bank region, and regionalized erodibility rating curves. BANCS is then applied for an entire reach or length of stream to estimate total sediment load to a stream from bank erosion.

BANCS consists of three components: Bank Erosion Hazard Index (BEHI) ratings, Near-Bank Stress (NBS) ratings, and a streambank erodibility rating curve. The BEHI rating identifies and scores physical features that affect erosion, including bank height, bank angle, root depth, root density, surface protection, and streambank material composition. Numeric scores are converted to categories of erosion hazard, rated as very low, low, moderate, high, very high, or extreme. The NBS rating incorporates the effect of streamflow and hydraulic stress in the near-bank region on erosion. The streambank erodibility curve is then developed by relating BEHI and NBS ratings to measured erosion rates at corresponding locations.

BEHI and NBS ratings are typically combined with an existing streambank erodibility rating curve to estimate an annual rate of bank erosion per linear foot. However, the only available curves did not represent the characteristics of sediment, soil cohesion, riparian vegetation types, hydrology, and geology of lower Esopus Creek, and sometimes did not cover the full range of BEHI and NBS rating combinations observed in lower Esopus Creek.[21]

All 17 stream geomorphology cross-sections were evaluated by field staff trained in Rosgen methods to obtain BEHI and NBS ratings. BEHI ratings were scored by the same field staff for all stream geomorphology cross-sections on every field visit; the average rating was used in the assessment. NBS ratings were estimated for all stream geomorphology cross-sections during the first three field visits (2012-2014) based on stream characteristics at the assessed location (channel pattern, depositional features, and cross-section shape) or ratio of near-bank maximum depth to bankfull depth (NBS methods 1 and 5). Since there were no regionally appropriate erodibility rating curves available for the lower Esopus Creek study area, the BANCS analysis was ultimately not used to predict bank erosion rates in the future without or with the Proposed Action in this assessment; bank erosion was instead estimated using bank pins, as described in the next section. The BEHI ratings were considered in conjunction with observed bank retreat data to qualitatively assess a given monitored location’s relative potential to erode. Results suggest there are local site conditions unrelated to duration of and exposure to a specific flow for each cross-section that influence retreat rates. Information on localized conditions is presented in Section 7.1.4, “Parameters Evaluated for the Technical Area Assessments – Flow Regime and Water Quality – Stream Management Plan Considerations.”

Bank Retreat (Erosion)

Stream bank erosion pins were installed near the 17 stream geomorphology cross-sections to measure bank erosion rates (in feet per year). Bank pins were installed by driving metal rebar (three to four feet in length) horizontally into the streambank at three different elevations. The bank pins were installed in 2012 through 2014 and measured at six field visits over the seven years of stream geomorphic monitoring from 2012 through 2018. **Figure 5.3-3** provides an illustrative view of bank pin configuration alongside a photo from the field.

[21] Available curves at the time of this assessment included two datasets developed in mountain streams in Colorado and Wyoming with high sediment supply of coarse material, one dataset based on North Carolina Piedmont streams, and one in a highly urbanized setting near Washington, D.C. with a drainage area of two square miles.

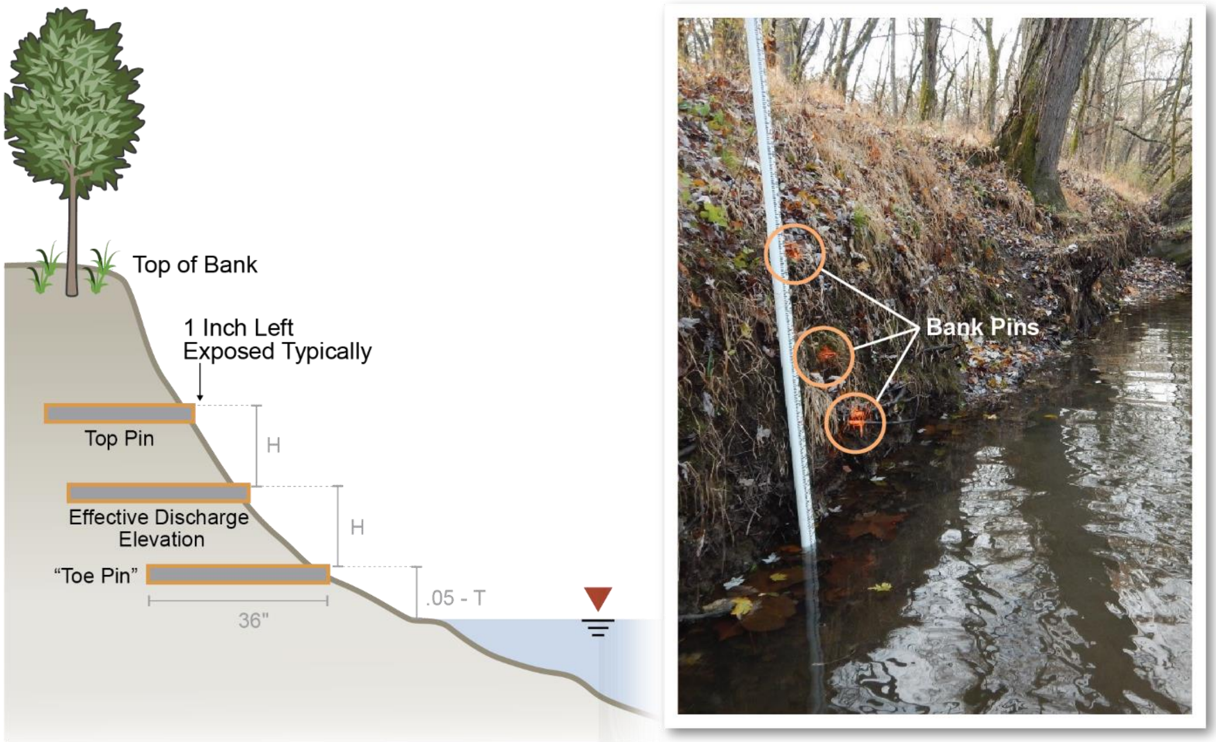

Figure 5.3-3. Illustrative View of Bank Pin Configuration (left) and Example of Bank Pins in Lower Esopus Creek (right)
Bank pins in the photograph are marked with orange paint

Bank retreat data were collected by measuring the length of exposed rebar (in feet) and comparing the findings with previous measurements. The change in the exposed length of a pin between field visits was recorded as bank retreat, or, in cases where the pin had been covered by sediment, as aggradation. The pins were measured on eight different field visits from 2012 through 2018 at each location where bank retreat and aggradation were observed, resulting in seven individual monitoring periods of varying durations. Retreat was calculated for each monitoring period (in feet) at each cross-section, as well as a sum across the monitoring periods at each cross-section.

The rate of bank retreat (in feet per year) was calculated by dividing the bank retreat (in feet) from each monitoring period by the duration of the monitoring period (in years) at each cross-section. The bank retreat rate was used to compare retreat rates across different monitoring periods. The bank retreat rate (in feet per year) at each cross-section was calculated as the average of retreat rate from the individual monitoring periods.

<u>Shear Stress</u>

An analysis of shear stress was conducted on the stream banks at each cross-section to identify whether certain conditions within lower Esopus Creek were predictive of observed bank retreat over the seven years of monitoring. Shear stress in a stream is the force created by the flow of water over the streambed and banks. A particle in the streambed or bank will mobilize when the shear stress acting on it is greater than the particle’s resistance to movement. Resistance to mobilization depends on particle size, orientation, embeddedness, and other environmental factors.

Critical shear stress (τ_c) defines the point of incipient motion, when particles along a streambed or bank become entrained (get moved or "mobilized") at a certain location. Critical shear stress is typically estimated as a function of the size of the bed and bank particles it can move, but in addition to sediment size, critical shear stress is also influenced by other factors including sediment composition, and soil properties, and vegetation.

D50 (median particle size) within the streambank was selected as the representative particle size to calculate critical shear stress.[22] The D50 of the particle size distributions of bank material were determined through sieve analysis at seven of the 17 cross-sections. At the remaining ten cross-sections, the D50 was estimated using site photographs and measured D50 values at nearby cross-sections.

Initial estimates of critical shear stress at each location were developed based on D50 values. This was done using standard geomorphic relationships for shear stress and particle size, in particular the Shields curve for motion of particles and a curve developed by Wildland Hydrology.[23] The Shields curve was used for particle sizes smaller than ten millimeters (mm). When the D50 value was greater than 10 mm, the curve developed by Wildland Hydrology was used to determine critical shear stress because it is considered more accurate than the Shields curve for particles of this size.[24]

Two adjustment factors were applied to the initial estimates of critical shear stress to account for soil properties and presence of vegetation at each cross-section. The first adjustment factor was used to account for the silt and clay percentage of the bank material. This adjustment factor was needed because the Shields curve assumes no interaction among sediment particles, so use of Shields' curve typically underestimates critical shear stress and overestimates erosion rates (Clark and Wynn, 2007).[25] In cohesive soils, the effects of inter-particle forces outweigh the influence of gravity in the resistance to erosion. Critical shear stress ($\boldsymbol{\tau_c}$) was estimated for each cross-section as a function of the percentage of silt and clay particles (SC) in the bank samples, following the below equation developed by Julian and Torres (2006).[26]

$$\tau_c = 0.1 + 0.1779(SC) + 0.0028(SC)^2 - 2.34e^{-5}(SC)^3$$

The second adjustment factor was applied based on vegetation present on the stream bank surface at each cross-section. The presence of vegetation increases bank strength through root structures and surface protection. Julian and Torres (2006) determined adjustment factors to critical shear stress based on bank strength indices derived by Huang and Nanson (1998).[27] An initial estimate of critical shear stress using

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[22] Bunte, Kristin; Abt, Steven R. 2001. Sampling surface and subsurface particle-size distributions in wadable gravel- and cobble-bed streams for analyses in sediment transport, hydraulics, and streambed monitoring. Gen. Tech. Rep. RMRS-GTR-74. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 428 p.

[23] Shields and Wildland Hydrology curves define critical shear stress as a function of particle size. Both curves are available in and were obtained from the RiverMORPH® software developed by Wildland Hydrology (www.rivermorph.com).

[24] Bunte, K., Abt, S.R., Swingle, K.W., Cenderelli, D.A., and Schneider, J.M. 2013. *Critical Shields values in coarse-bedded steep streams.* Water Resour. Res., 49: 7247-7447.

[25] Clark, L.A., and Wynn, T.M. 2007. *Methods for determining streambank critical shear stress and soil erodibility: Implications for erosion rate predictions.* Transactions of the ASABE. 50(1): 95-106.

[26] Julian, J.P., and Torres, R. 2006. *Hydraulic erosion of cohesive riverbanks.* Geomorphology, 76: 193-206.

[27] Huang, H.Q., and Nanson, G.C. 1998. *The influence of bank strength on channel geometry: an integrated analysis of some observations.* Earth Surf. Process. Landforms, 23: 865-876.

the Shields curve was multiplied by these adjustment factors based on vegetation present at each cross-section to determine adjusted critical shear stress values at each cross-section. If both silt and clay percentage and vegetation were dominant in providing resistance to bank erosion, then critical shear stress was estimated using both available adjustment factors.

Once critical shear stress values were calculated and adjusted, rating curves were used to determine at what streamflow critical shear stress would be exceeded resulting in mobilized particles. The shear stress rating curves for each cross-section were derived from HEC-RAS model output. Shear stress over a range of streamflow was extracted from the HEC-RAS model. Shear stress was plotted as a function of streamflow.

Next, a time series of shear stress was estimated at each cross-section using a streamflow time series modeled by OST and the shear stress rating curve from HEC-RAS. For both the future without and with the Proposed Action, modeled streamflow was estimated at each cross-section by scaling Mount Marion streamflow to the cross-section location. This was done by applying the ratio of each cross-section's drainage area to that of Mount Marion, and combining this with flow from Ashokan Reservoir modeled by OST. On each day of the streamflow time series, the corresponding shear stress value was determined from the shear stress rating curve derived from HEC-RAS model output. For streamflow from the time series that fell between the discrete streamflow rates modeled in HEC-RAS, the shear stress value was interpolated from the next lowest and highest streamflow shear stress values within the HEC-RAS model.

The total number of days where modeled shear stress was above critical shear stress within each of the bank pin monitoring periods was then determined for each cross-section. Average annual days above critical shear stress was calculated by dividing the days above critical shear stress by the total number of days in each bank pin monitoring period. Bank retreat rates were then compared to frequency of streamflow that cause critical shear stress to be exceeded within each monitoring period (measured in days). This comparison was completed at each cross-section.

<u>Stream Power</u>

A stream power analysis was conducted to assess overall stream stability between the future without and with the Proposed Action. Stream power is often used as a measure of the potential for adjustments in channel pattern, profile, or dimension to occur. A higher calculated stream power would be expected to have a greater potential to mobilize sediment within the stream. Stream power (Ω) and specific stream power (ω) are defined by the following equations:

$$\Omega = \gamma Q S \qquad\qquad \omega = \frac{\gamma Q S}{w}$$

where γ is the specific weight of water, Q is the streamflow as calculated by the HEC-RAS model, w is the width at the given HEC-RAS streamflow, and S is the stream slope calculated during field assessments. Potential changes to stream power between the future without and with the Proposed Action were considered as part of the assessment.

Water Quality

Baseline water quality conditions were established by: (1) compiling historical water quality observations from DEP and NYSDEC; (2) analyzing seasonal patterns of turbidity levels, TSS, temperature, dissolved oxygen, and pH within lower Esopus Creek based on the available data; (3) evaluating the relationship of turbidity levels to streamflow magnitude; (4) comparing distributions of daily turbidity levels for various locations throughout the study area; (5) comparing concurrent data for turbidity levels and temperature at various locations throughout the study area; and (6) comparing turbidity levels and temperature in lower

Esopus Creek to the turbidity levels, temperature, and flow rates of Ashokan Reservoir (i.e., spills and releases).

Potential benefits and impacts to the water quality of lower Esopus Creek between the future without and with the Proposed Action were evaluated by: (1) characterizing the distributions of turbidity levels in flows from Ashokan Reservoir for the future with the Proposed Action, and analyzing those distributions for wet, normal, and dry years; (2) comparing seasonal patterns of turbidity levels for both spills and releases for the future without and with the Proposed Action, including consideration of in-stream and watershed turbidity level contributions and analyzing those comparisons for wet, normal, and dry years; (3) comparing time series of flow rates and turbidity levels for both spills and releases during episodic turbidity events; (4) comparing the percent of time that turbidity levels in lower Esopus Creek would range from 0 to 100 NTU in 5 to 10 NTU increments (i.e., 0 to 5 NTU, 5 to 10 NTU, 10 to 15 NTU, 15 to 20 NTU, 20 to 25 NTU, 25 to 30 NTU, 30 to 40 NTU, 40 to 50 NTU, 50 to 60 NTU, and greater than 60 NTU) for the future without and with the Proposed Action, and analyzing those comparisons by season and for wet, normal, and dry years; and (5) comparing seasonal temperature differences in lower Esopus Creek and Ashokan Reservoir for the future without and with the Proposed Action.

KENSICO RESERVOIR STUDY AREA

The water resources and water quality impact assessment for the Kensico Reservoir study area consisted of: (1) describing baseline conditions including (a) water quality, particularly turbidity levels, in the flows from Ashokan to Kensico Reservoirs; and (b) describing the previously identified areas of alum floc deposition; (2) establishing future conditions without the Proposed Action and any upcoming proposed projects that would potentially result in changes to water resources and water quality within the study area; (3) establishing future conditions with the Proposed Action based on the delay of dredging and environmental considerations associated with dredging; and (4) analyzing potential changes to water resources and water quality based on the application of alum and the anticipated total area and amount of alum floc deposition.

The assessment of alum application at Kensico Reservoir addressed the delay of dredging and environmental considerations associated with dredging. Two types of potential changes to water quality at Kensico Reservoir were discussed: (1) the direct physical effects of turbidity and dredging to remove alum floc (e.g., altered bathymetry of Kensico Reservoir); and (2) the potential for changes in water quality from potentially suspended aluminum associated with particles in the water column and temporary increase in turbidity levels from dredging.

The floodplains impact assessment for the Kensico Reservoir study area consisted of an assessment of the impacts of a delay of dredging and also identified specific environmental considerations of dredging activities that could occur within designated flood zones.

5.3.2 PUBLIC POLICY, LAND USE, AND ZONING

The public policy, land use, and zoning assessment consisted of evaluating the potential for the Proposed Action to result in direct or indirect effects resulting from conditions that conflicted with applicable public policies or were not compatible with existing land use and zoning.

The impact assessment consisted of: (1) establishing and describing baseline conditions within the study areas by identifying existing land uses, zoning districts, and relevant public policies, including adopted State, county, neighborhood, and community plans; (2) identifying any upcoming future development projects, plans for public improvements, and pending zoning actions or other public policy actions within the study areas to describe any changes that have the potential to affect land use and zoning patterns and trends; and (3) assessing if future conditions with the Proposed Action would result in short- or long-term changes to applicable public policies, land uses, or zoning districts.

5.3.3 SOCIOECONOMIC CONDITIONS

The socioeconomic assessment consisted of evaluating the potential for the Proposed Action to result in direct, indirect, and/or induced effects to factors that influence the socioeconomic conditions or character of the lower Esopus Creek study area, including land use, population, housing, and economic activity.

Delay of dredging would not result in direct or indirect displacement of residences or businesses, result in changes to population or housing, or alter business or employment in the area. Any dredging in the future would be temporary in nature and no socioeconomic environmental considerations of dredging were identified. Neither a delay of dredging nor dredging activities are anticipated to adversely influence socioeconomic conditions or character of the Kensico Reservoir study area. Therefore, further assessment of socioeconomic conditions in the Kensico Reservoir study area is not warranted.

For the lower Esopus Creek study area, the impact assessment consisted of: (1) establishing and describing socioeconomic conditions and trends using available data from federal, State, and local agencies and other sources, such as local chambers of commerce; (2) identifying any upcoming future changes in the study area that could affect socioeconomic conditions; and (3) evaluating whether the Proposed Action would result in benefits or impacts along lower Esopus Creek due to: (a) changes in housing prices; (b) direct business displacement; (c) indirect business displacement; and/or (d) benefits or adverse effects on a specific industry. This included an analysis of potential effects on agriculture and local business operations as a result of the Proposed Action. The potential effects of the Proposed Action on housing prices were identified through a housing price analysis to compare single-family housing prices along the lower Esopus Creek waterfront (i.e., homes on or across the street from the waterfront) to those within a 0.5-mile of lower Esopus Creek and along the waterfront of a reference creek. Questionnaires and the IMPLAN input-output model, where appropriate, were also used to assess potential differences to socioeconomic conditions for the future with the Proposed Action as compared to the future without the Proposed Action, as described below.

HOUSING PRICE ANALYSIS

The housing price analysis of single-family homes was performed to determine whether the Proposed Action would have the potential to affect housing prices of homes located along the lower Esopus Creek waterfront (i.e., on or across the street from the waterfront). The analysis compared the market value of these homes to properties located within a 0.5 mile of lower Esopus Creek and along the nearby Rondout Creek waterfront.[28] Single-family housing is the predominant land use of properties located in both these areas and their market values are expected to be affected by the same factors. Rondout Creek was chosen as a comparable stream in the region because it is located near lower Esopus Creek, is within the study area (it extends from the Town of Wawarsing to the Village of Saugerties), is tributary to the Hudson River, and is located downstream of a DEP reservoir but is not subject to the IRP.

Market value and housing characteristic data of 550 single-family homes within 2,500 feet (approximately a 0.5 mile) of the two creeks from 2007 to 2017 were obtained from Ulster County's Parcel Geodatabase. Market value is determined by Ulster County property assessors and was provided in a dataset compiled by the New York State Department of Tax and Finance's Office of Real Property Tax Services (NYS-ORPS). The analysis compared changes of property values for homes across three time periods: (1) 2007 to 2013; (2) 2013 to 2017; and (3) the full time period from 2007 to 2017. The year 2013 was selected as a comparison point for this analysis as it is the same year that the IRP was implemented. The housing price analysis also corrected for differences in market value that may be

[28] The market value of a property is estimated using actual sale prices of similar homes and characteristics of the property. An assessed value is for tax purposes and is usually lower than the market value estimated by the property assessor.

attributable to factors other than the presence of or conditions within lower Esopus Creek (e.g., lot size, year built).

Socioeconomic Survey Methodology

In fall 2018, approximately 2,900 questionnaires were sent to residents and businesses within a 0.5 mile of lower Esopus Creek. A residential questionnaire asked general questions about participation in recreational activities along lower Esopus Creek to capture responses from residents along lower Esopus Creek and those who may not live in close proximity but use lower Esopus Creek for recreational purposes or general enjoyment. The business questionnaires were targeted to five specific industries: retail businesses, lodgings, farms, marinas, and parks. The objective of the survey was to collect estimates of the amount each household spent or the revenue generated by each business or organization on activities or services related to the use and enjoyment of lower Esopus Creek by season.

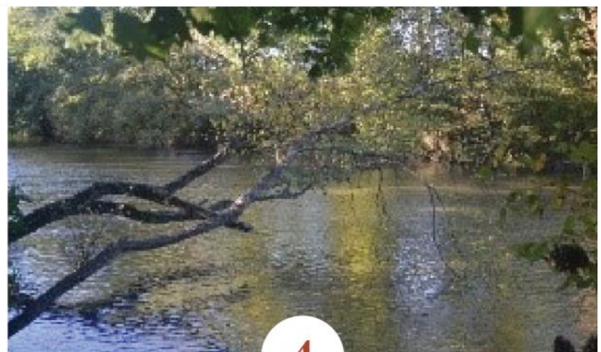
Following a set of instructions for completing the questionnaire (Section A), the residential questionnaire had two distinct sections: the first section, Section B, collected relevant number of days residents spent participating in recreational activities along lower Esopus Creek by season and activity and financial information associated with this use of lower Esopus Creek. The second section, Section C, asked respondents to indicate how different streamflow and water quality conditions would impact their participation in recreational activities along lower Esopus Creek. In total, five streamflow and water quality conditions were presented to respondents and are shown in **Figure 5.3-4:** (1) *moderate flow, clear water*; (2) *moderate flow, cloudy water*; (3) *high flow, very cloudy water*; (4) *high flow, clear water*; and (5) *very low flow*. The residential questionnaire is provided in **Appendix B.**

Similarly, the business questionnaire had two sections: the first collected financial information and the second asked respondents to indicate how different flow and water quality conditions would impact business (e.g., sales, occupancy). The same five streamflow and water quality conditions presented in the residential questionnaire were also used for the business questionnaire, as shown in **Figure 5.3-4.** The business questionnaire for each of the five industries are provided in **Appendix B**.

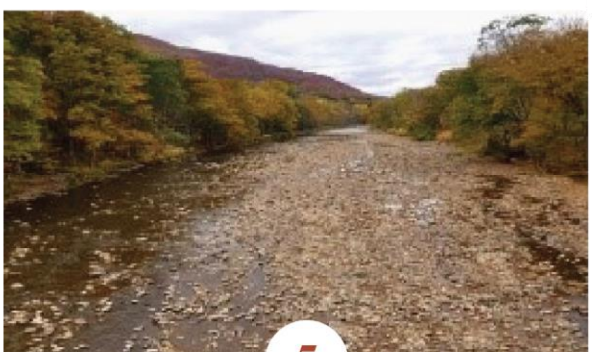
1
Moderate flow,
clear water conditions

2
Moderate flow,
cloudy water conditions

3
High flow,
very cloudy water conditions



4
High flow,
clear water conditions



5
Very low flow
(i.e., drought)

These photos capture the majority of flow and water quality conditions that occur within lower Esopus Creek.

Figure 5.3-4
Lower Esopus Creek Survey Photos

These questionnaires were distributed to residents and businesses that may be affected by conditions in lower Esopus Creek through potential changes in use or sales. To identify residents and businesses to participate in the survey, a list was prepared of names, businesses, and addresses within Ulster County using data purchased from InfoUSA. Names, businesses, and addresses purchased from InfoUSA included those within a 0.5 mile of lower Esopus Creek. The list of purchased addresses was further supplemented using names and addresses identified through a desktop survey of the area to identify other businesses located along lower Esopus Creek; volunteers that had supported prior data collection efforts (study volunteers); and others that wanted to participate in the survey as identified by the ARWG and other stakeholders. The final list was edited to include only residents and businesses with complete mailing addresses that were then compiled into distribution lists. The lists were used to mail questionnaires and instructions for completion, inviting each included resident or business to participate in the survey. Additional details on development of the survey distribution list for each surveyed group are as follows and summarized in **Table 5.3-1**:

- Resident Surveys – Of the 4,904 resident addresses provided within the study area in the data set purchased from InfoUSA, there were 665 available addresses for properties adjacent to lower Esopus Creek (i.e., within a 500-foot corridor on either side of lower Esopus Creek) and all of these were included in the survey distribution list. The remaining 4,239 addresses provided for the study area were for residents who live within approximately a 0.5 mile of lower Esopus Creek, but not adjacent to lower Esopus Creek (i.e., within 500 feet). Of these, 1,500 available addresses were randomly selected to provide geographic distribution along lower Esopus Creek and added to the survey distribution list. The resident distribution list was supplemented with an additional 491 names and addresses obtained through desktop search or provided by the ARWG and other stakeholders.
- Retail Businesses – 170 retail business establishments and addresses within the study area were provided in the data set purchased from InfoUSA and used for the retail business survey distribution list. This list was supplemented with an additional 23 names and addresses obtained through the desktop search or from a list of study volunteers.
- Lodging – Ten lodging establishments and addresses within the study area were provided in the data set purchased from InfoUSA and were used for the lodging survey distribution list. This list was supplemented with an additional five names and addresses provided through the desktop search.
- Farms – Seven farm addresses within the study area were provided in the data set purchased from InfoUSA and were used for the farm survey distribution list. This list was supplemented with an additional 14 names and addresses provided by the desktop search, ARWG, and other stakeholders.
- Parks – One park name and address was provided within the study area in the data set purchased from InfoUSA and was used for the park survey distribution list. This list was supplemented with an additional eight names and addresses provided by the desktop search and study volunteers.
- Marinas – One marina name and address was provided within the study area in the data set purchased from InfoUSA and was used for the marina survey distribution list. This list was supplemented with an additional six names and addresses provided by the desktop search, ARWG, and other stakeholders.

The number of questionnaire responses received from the five business sectors were not high enough to support a quantitative economic analysis. Instead, responses were summarized and used to qualitatively assess the potential benefits and impacts of differences between the future without and with the Proposed Action for these groups.

For the residents, respondents were instructed to leave question cells as blanks if they did not participate in an activity, did not spend money on an activity or felt there would be no change in their recreational activity levels associated with streamflow and water quality conditions presented in the questionnaire. Therefore, prior to analyzing the survey responses, blank responses were set to zero, where applicable.[29] Where respondents indicated the average number of days recreating was a value greater than 90 days per season (each season being approximately three months), the value was set to 90.

Resident responses were used to determine expected changes in participation in recreational activities by season for each respondent. This was done by calculating the product of the number of days spent participating in recreational activities along lower Esopus Creek by season (responses to question B3) with how participation in these activities may change based on different streamflow and water quality conditions (responses to questions C1 to C5). This assumed that lower Esopus Creek exhibited the streamflow and water quality conditions presented in questions C1 to C5 for the time period the participant would typically engage in recreational activities. For example, if a respondent indicated they swim in lower Esopus Creek for an average of four days in the summer and reported that a particular water quality and streamflow condition would increase their participation in recreational activities by 50 percent, the increase in recreational swimming in the summer for that participant would be two days.

Respondents who indicated they participated in zero days of recreational activities along lower Esopus Creek but provided a percent change on their recreational activity levels based on the scenario presented were not used in the calculations. Therefore, a total of 105 responses were used to calculate the change in days per recreational activity for respondents who live adjacent to lower Esopus Creek and 87 responses were used to calculate the change in days per recreational activity for respondents who live between 500 feet and a 0.5 mile of lower Esopus Creek.

[29] For questionnaires that were otherwise complete, a blank response for questions B2, B3, B4, and C1 to C5 was assumed to indicate that the respondent either did not use or would not experience a change in recreational use of lower Esopus Creek for the condition described (see Appendix B).

Table 5.3-1. Summary of Questionnaire Distribution

Source	Residents		Businesses					Total
	Adjacent to Lower Esopus Creek (within 500 feet)	Between 500 feet and a 0.5 mi. of Lower Esopus Creek	Retail	Lodging	Farms	Marinas	Parks	
InfoUSA	665	1,500	170	10	7	1	1	**2,354**
Desktop Search and Study Volunteers	473	0	23	5	13	5	8	**527**
Stakeholders	18	0	0	0	1	1	0	**20**
Total Questionnaires Distributed	**1,156**	**1,500**	**193**	**15**	**21**	**7**	**9**	**2,901**
Total Questionnaire Responses Received	**129**[1]	**167**[2]	**18**	**8**	**8**	**0**	**7**	**337**

Notes:

1 Fourteen questionnaires were excluded from the analysis since there was insufficient data to support the assessment (i.e., the surveys were incomplete). A total of 115 responses were available for analysis. Of those, some respondents indicated they participated in zero days of recreational activities along lower Esopus Creek and therefore their reported change in participation in recreational activities was not used in the calculations. Therefore, 105 of the questionnaire responses received were used to calculate the change in days per recreational activity for respondents who live adjacent to lower Esopus Creek.

2 Sixty-two questionnaires were excluded since responses were insufficient to support the analysis; however, of these, 32 contained comments which provided context for the overall assessment of recreational use along lower Esopus Creek. A total of 105 responses were available for analysis. Excluding respondents who indicated they participated in zero days of recreational activities along lower Esopus Creek, a total of 87 questionnaire responses received were used to calculate the change in days per recreational activity for respondents who live between 500 feet and a 0.5 mile of lower Esopus Creek.

IMPLAN MODELING

IMPLAN is an input-output based regional economic assessment modeling system that is commonly used for evaluating differences in economic metrics for various alternatives. It consists of a software package and data files that are available at different geographic levels and updated every year. The IMPLAN data files include transaction information (intra-regional and import/export) on 536 industrial sectors and data on more than 20 different economic variables. For this study, the IMPLAN system was populated with data available for Ulster County (2017)[30] to evaluate the potential for benefits or impacts between the future without and with the Proposed Action based on questionnaire responses and potential differences in streamflow and water quality conditions between the future without and with the Proposed Action.

[30] IMPLAN Group, LLC. 2019. IMPLAN 2017 data file for Ulster County, New York, Accessed 1/17/2019.

Overall, the response rate for the residents was sufficient for conducting a quantitative assessment of the responses received. Responses were used to calculate average annual spending as a result of participation in recreational activities whether no spending ($0) or some spending was reported. The seasonal median change in frequency of overall activities based on responses from Section C of the questionnaire was applied to the modeled expected differences in days lower Esopus Creek would be in the conditions presented in each scenario photo between the future without and with the Proposed Action. Using this methodology, the change in days over and above typical activity levels required for the IMPLAN analysis could be generated for those that live adjacent to lower Esopus Creek and those that live between 500 feet and a 0.5 mile of lower Esopus Creek.

5.3.4 OPEN SPACE AND RECREATION

The open space and recreation assessment consisted of evaluating the potential for the Proposed Action to alter the quality or availability of open spaces for continued public and private recreational use within the lower Esopus Creek and Kensico Reservoir study areas.

The impact assessment consisted of: (1) establishing and describing the baseline conditions within the study areas by mapping existing uses of open space and recreational resources adjacent to each waterbody; (2) identifying any upcoming plans to expand or create new open space or recreational resources within the study areas that have the potential to affect open space or recreational resources; and (3) evaluating whether the Proposed Action would restrict public access to or displace open spaces or recreational resources as compared to the future without the Proposed Action.

LOWER ESOPUS CREEK

Additional analyses were conducted for the lower Esopus Creek study area as follows.

SWIMMING

To evaluate the potential for changes to the suitability of swimming conditions along lower Esopus Creek, the following methodology was used to evaluate differences between the future without and with the Proposed Action.

- **Flow Conditions**: Swimming can be unsafe when streamflow is high. The analysis calculated the difference in days above various streamflow rates between 15 and 1,000 MGD (23 and 1,547 cfs) over the summer swimming season when the beaches are typically open. The analysis considered whether these differences would have the potential to affect recreational swimming opportunities along lower Esopus Creek.

- **Water Quality Conditions:** Cloudy water conditions may result in unsuitable swimming conditions since high turbidity levels limit visibility. The analysis compared turbidity levels of streamflow in the future without and with the Proposed Action and evaluated whether these differences have the potential to affect recreational swimming opportunities within lower Esopus Creek. In addition to turbidity levels, the analysis also considered bacteriological water quality criteria for safe swimming as regulated by NYSDOH.

FISHING

Suitable fishing conditions were evaluated using results of the survey conducted as part of the socioeconomic conditions assessment (see Section 7.3, “Socioeconomic Conditions”). OST modeling was used to tabulate the number of days in the peak fishing seasons (spring, summer, and fall) in the future without and with the Proposed Action in which lower Esopus Creek conditions would classify as preferred conditions identified by socioeconomic survey responses received.

BOATING

Similar to fishing, suitable year-round boating conditions were evaluated using results of the survey conducted as part of the socioeconomic conditions assessment (see Section 7.3, "Socioeconomic Conditions").

5.3.5 CRITICAL ENVIRONMENTAL AREAS

For any Critical Environmental Areas (CEAs), defined in SEQRA Part 617.14(g), located within the study area, the potential impacts of the Proposed Action on the environmental characteristics of the CEAs must be evaluated pursuant to Section 617.7.

No CEAs are located within the lower Esopus Creek study area. The potential for the Proposed Action to result in changes to the exceptional or unique character of CEAs within the surrounding Kensico Reservoir study area was assessed. The impact assessment consisted of: (1) identifying and describing baseline conditions within the Kensico Reservoir study area by mapping the one existing CEA; (2) summarizing results of desktop analyses to identify any upcoming changes, planned, or under development, that have the potential to impact the CEA; and (3) analyzing the potential impacts to the CEA by evaluating if the Proposed Action would potentially alter the exceptional or unique character of the CEA as compared to the future without the Proposed Action.

5.3.6 HISTORIC AND CULTURAL RESOURCES

The historic and cultural resources assessment consisted of evaluating the potential for the Proposed Action to result in any ground disturbance or inundation that may affect archaeological resources or a historically important building, structure, or object. Architectural resources generally include historically important buildings, structures, objects, sites, and districts. Archaeological resources are physical remains, usually subsurface, of the prehistoric, Native American, and historic periods, such as burials, foundations, artifacts, wells, and privies.

The impact assessment consisted of: (1) identifying and describing historic and cultural resources and previous disturbance areas and activities within the study areas; (2) summarizing results of consultations with municipalities and counties located within the study areas to identify any upcoming changes, planned or under development, that have the potential to affect historic or archaeological resources; and (3) analyzing the potential impacts to historic and cultural resources by evaluating whether the Proposed Action would potentially disturb or alter the integrity of historic and cultural resources as compared to the future without the Proposed Action.

Additionally, to evaluate the potential for incremental impact along lower Esopus Creek, the historic and cultural resource analysis included a review of the State Historic Preservation Office's (SHPO's) online resource mapper and consultation with SHPO to identify areas where sensitive resources are located. These locations were reviewed against information collected from Section 7.1, "Water Resources and Water Quality" assessment for the lower Esopus Creek study area to determine whether identified resources would be co-located with areas where there would be differences in potential inundation or erosion and deposition between the future without and with the Proposed Action. No cultural resource surveys were conducted as part of this assessment.

5.3.7 AESTHETIC (VISUAL) RESOURCES

The visual resources assessment consisted of identifying potential changes to views to or from visual resources (e.g., obstruction of views, diminishment of public enjoyment and appreciation of a resource) within the study areas as a result of the Proposed Action. Based on CEQR guidance, a 400-foot study area is appropriate for assessment of views by a pedestrian at publicly accessible visual resources and was used for the assessment. Activities of a potential viewer, such as routine travel or recreational and tourism activities, were identified to assess the significance of potential changes to views. In addition, view corridors that extend beyond the study areas were considered where scenic vistas/views encompass lower Esopus Creek or Kensico Reservoir.

NYSDEC provides a list of 16 categories of State aesthetic and visual resources that should be included in an evaluation of the potential for impacts to visual resources (see **Table 5.3-2**). Local resources are also considered in this analysis, such as parks, historic structures, and landmarks. In addition, the assessment included an evaluation of the Hudson River, a designated American Heritage River. American Heritage Rivers are designated by federal Executive Order 13061 to protect natural resources and the environment, support economic revitalization, and to preserve historic and cultural resources. Open space or historic resources located outside of the 400-foot study area were not evaluated.

The impact assessment consisted of: (1) describing the existing aesthetic views to and/or from the visual resources within the study areas, including turbidity levels of streamflow and exposed shoreline during typical conditions; (2) identifying any upcoming proposed projects and assessing if the future conditions would affect aesthetic views to and/or from the visual resources within the study areas; and (3) analyzing potential impacts from the Proposed Action through a qualitative determination of the potential changes to views to and/or from visual resources (e.g., obstruction of views, diminishment of public enjoyment and appreciation of a resource) within the study areas as compared to the future without the Proposed Action.

For resources along lower Esopus Creek, turbidity levels of streamflow was considered as part of the assessment to evaluate potential changes in views to and from lower Esopus Creek between the future without and with the Proposed Action.

Table 5.3-2. Types of Aesthetic and Visual Resources Considered for Assessment

Type	Description
National/State Register of Historic Places	Listed or eligible for listing on the National or State Register of Historic Places (sites, districts, buildings, structures, and objects that are deemed worthy of preservation).
State Parks	Defined by State Parks, Recreation and Historic Preservation Law §3.09 to encourage, promote, and provide recreational opportunities.
Heritage Areas	Designated by New York State as special places to honor history, celebrate the present, and plan the future of our communities.
State Forest Preserve/State Forests	State Forest Preserves are designated by the New York State Legislature with Constitution Article XIV, and protected as "forever wild." State Forests are lands acquired and managed by NYSDEC as Reforestation Areas, Multiple-Use Areas, Unique Areas, and State Nature and Historic Preserves, as authorized by the 1929 State Reforestation Act.
National/State Wildlife Refuge, State Wildlife Management Areas	National Wildlife Refuges are designated public lands and waters given special protection by the National Wildlife Refuge System Administration Act 16 U.S. Code (USC) 668dd-668ee and amended by Public Law 105-57 to conserve fish, wildlife, and plants. State Game Refuges are designated by NYSDEC's Environmental Conservation Law §11-2105 as lands for the protection of fish, wildlife, and State Wildlife Management Areas are owned by the State under the control and management of NYSDEC's Division of Fish, Wildlife, and Marine Resources for the protection and promotion of fish and wildlife resources.
National Natural Landmark	Designated by the Secretary of the Interior and defined by 36 CFR Part 62 as conservation sites that contain outstanding biological and geological resources, including both public and private lands, and are selected for their condition, illustrative value, rarity, diversity, and value to science and education.

Table 5.3-2. Types of Aesthetic and Visual Resources Considered for Assessment (Continued)

Type	Description
National Park and System, Recreation Areas, Seashores, Forests	Established by an act of Congress and defined by 16 USC §1c to identify Parks, Preserves, Battlefields, Memorials, Recreation Areas, Seashores, Monuments, Rivers, Parkways, and Cemeteries as significant resources.
National/State Wild, Scenic, or Recreational Rivers	Established by an act of Congress and defined by Public Law 90-542 under the Wild and Scenic Rivers Act and New York State Wild, Scenic, and Recreational Rivers System Act, defined under NYSDEC's ECL §15-27 for outstanding natural, cultural, and recreational values in a free-flowing condition.
Scenic site, area, lake, reservoir, or highway	Designated and defined by NYSDEC's ECL Article 49, Protection of Natural and Man-Made Beauty or highways designated by the U.S. Department of Transportation Federal Highway Administration or the New York State Department of Transportation as scenic roads and byways.
Scenic Areas of Statewide Significance	Designated by the New York State Department of State (NYSDOS) to identify the scenic qualities of coastal landscapes that possess inherent scenic qualities, including the presence of water, dramatic shorelines, expansive views, historic landings, working landscapes, and great estates.
National/State Trails	Federal trails, as defined by 16 USC Chapter 27 and designated by the Secretary of the Interior or the Secretary of Agriculture and State trails, as part of New York State Parks, Historic Sites, and Forests to provide a variety of outdoor recreation uses.
State Nature and Historic Preserve Areas	Designated by the State Legislature and defined by Section 4 of Article XIV of the State Constitution for the protection of natural resources, development of agricultural lands, and to conserve and protect its natural resources and scenic beauty and encourage the development and improvement of its agricultural lands for the production of food and other agricultural products.
Bond Act Properties	Bond Act properties are properties purchased under the "exceptional scenic beauty" or "open space" category of the Environmental Bond Act of 1986, established by the State Legislature.
National Heritage Areas	National Heritage Areas are places where historic, cultural, and natural resources combine to form cohesive, nationally important landscapes.
American Heritage River	The American Heritage Rivers Protection Program, created by an Executive Order 13061, and designated by the U.S. Environmental Protection Agency to advance three objectives: natural resource and environmental protection, economic revitalization, and historic and cultural preservation.
Local	Defined and/or designated by regional planning entities, such as counties, and local communities, such as municipalities.

5.3.8 NATURAL RESOURCES

The natural resources assessment consisted of identifying the potential for the Proposed Action to result in changes to natural resources within the lower Esopus Creek and Kensico Reservoir study areas. The natural resources assessment included an evaluation of aquatic resources, wetland resources, and vegetation and wildlife resources.

AQUATIC (BENTHIC AND FISH) RESOURCES

Aquatic resources include organisms that live in water, and in particular, benthic macroinvertebrates, vertebrate (fish) species, and submerged aquatic vegetation (SAV). The impact assessment methodology for aquatic resources varied between the lower Esopus Creek and Kensico Reservoir study areas and is described for each study area below.

WETLANDS AND FLOODPLAIN FORESTS

There are three types of Cowardin Systems mapped in the study areas: palustrine, riverine, and lacustrine. Palustrine wetlands are freshwater, non-tidal wetlands dominated by trees, shrubs, perennial and annual emergent vegetation, and emergent mosses and lichens. Riverine wetlands are flowing waters with varying substrate types (boulders, cobbles, gravel, sand or silt) and naturally fluctuating water levels. Lacustrine systems are lakes or reservoirs, such as the Ashokan or Kensico Reservoirs, that feature submerged and emergent aquatic vegetation. Vegetation includes trees, shrubs, and herbaceous plants. The impact assessment for wetlands and floodplain forests within lower Esopus Creek and Kensico Reservoir study areas consisted of: (1) mapping and describing conditions of previously identified wetlands within the study areas; (2) establishing future conditions without the Proposed Action due to natural processes and any upcoming proposed future projects in the study areas; and (3) analyzing the potential for short- and long-term impacts to wetlands and floodplain forests from differences between the future without and with the Proposed Action. Additional methodology for the wetlands impact assessment within lower Esopus Creek is provided below.

VEGETATION AND WILDLIFE

Wildlife includes birds, mammals, reptiles, and amphibians, including threatened or endangered species, as well as those of special concern. For vegetation and wildlife resources, the impact assessment within the lower Esopus Creek and Kensico Reservoir study areas consisted of: (1) identifying and describing conditions of vegetation and common and protected wildlife that has the potential to occur within the study areas based on geospatial data such as the 2011 National Land Cover Dataset, topographic maps, the 2000-2005 New York State Breeding Bird Atlas, the New York State Amphibian and Reptile Atlas Project, the NYSDEC Nature Explorer, NYSDEC Environmental Mapper, Ecological Communities of New York State (Edinger et al., 2014),[31] and previous field surveys conducted in the study areas; (2) establishing future conditions without the Proposed Action due to natural processes and any upcoming proposed future projects in the study areas; and (3) analyzing the potential for short- and long-term impacts by evaluating whether the Proposed Action would potentially cause a disturbance to wildlife or terrestrial habitat within the surrounding areas as compared to the future without the Proposed Action. Additional methodology for the vegetation and wildlife impact assessment within lower Esopus Creek is provided below.

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[31] Edinger, G.J., D.J. Evans, S. Gebauer, T.G. Howard, D.M. Hunt and A.M. Olivero (editors). 2014. Ecological Communities of New York State. Second Edition; A Revised and Expanded Edition of Carol Reschke's Ecological Communities of New York State. New York Natural Heritage Program. New York State Department of Environmental Conservation, Albany, NY.

LOWER ESOPUS CREEK STUDY AREA

In the summer of 2006, the spring and summer of 2009, and the spring of 2010, natural resource surveys were conducted in the portion of the lower Esopus Creek study area from the Ashokan Release Channel to Mill Pond Dam. These included surveys of vegetation, wetlands, and aquatic and terrestrial resources. The natural resource surveys, together with existing local policies relevant to the protection of natural resources in the area, and data on historical discharges to the Ashokan Release Channel from Ashokan Reservoir, were summarized to describe baseline conditions. For areas downstream of the spillway confluence to the Hudson River, baseline conditions were described to the greatest extent practicable from field analyses, surveys, and results of landowner surveys and interviews conducted in 2011 through 2018. In addition, any existing studies, data, and published reports were utilized to supplement natural resource surveys.

AQUATIC (BENTHIC, FISH, AND SUBMERGED AQUATIC VEGETATION) RESOURCES

DEP conducted annual fish and stream macroinvertebrate community surveys along lower Esopus Creek in 2009, 2012, 2013, 2014, and 2017. To complete the assessment of aquatic resources within lower Esopus Creek, data obtained in fish and macroinvertebrate sampling efforts were compiled, and metrics recommended for use in data analysis by the EPA (1999)[32] and/or used by NYSDEC's Stream Biomonitoring Unit (SBU)[33] were computed. These metrics summarize particular aspects of community structure.

The macroinvertebrate metrics are total taxa richness, EPT richness (the number of mayfly *(Ephemeroptera)*, stonefly *(Plecoptera)*, and caddisfly *(Trichoptera)* taxa - the most sensitive macroinvertebrate groups), Hilsenhoff Biotic Index (a measure of organic pollution), Nutrient Biotic Index (for Phosphorus), and Percent Model Affinity (a measure of the degree of similarity to what the SBU considers a model State stream community). NYSDEC's SBU protocol was used to derive a Biological Assessment Profile score from the macroinvertebrates metrics. This score was used to determine the overall health of the benthic community. The SBU's Impact Source Determination protocol was also used to identify the source of potential impacts to stream communities.

In addition, NYSDEC (Bureau of Fisheries) electrofishing survey data from 2014 to 2016 collected at deep water locations in the Town of Saugerties, Town of Kingston, and Town of Marbletown were reviewed and information on fish stocking in lower Esopus Creek was obtained from the Federated Sportsmen of Ulster County. Finally, for federally- or State-listed threatened or endangered fish populations at the confluence of lower Esopus Creek and the Hudson River, a literature review was performed to identify the types and nature of potential impacts, if any, that could occur on these populations in the future without and with the Proposed Action.

The overall approach to the fisheries assessment was to compare potential differences in streamflow and water quality conditions between the future without and with the Proposed Action and to determine if those potential changes would affect aquatic resources. A literature review and a multi-species assessment based on Habitat Suitability Indices (HSI) was conducted to inform and support the assessment and comparison of the future without and with the Proposed Action. Quantitative HSI analyses were performed for variables that had the potential to differ between the future without and with the Proposed

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[32] Barbour, M.T., J. Gerritsen, B.D. Snyder, and J.B. Stribling. Rapid Bioassessment Protocols for Use in Streams and Wadeable Rivers: Periphyton, Benthic Macroinvertebrates and Fish. Second Edition. EPA 841-B-99-002. U.S. Environmental Protection Agency; Office of Water; Washington, D.C.

[33] Smith, Alexander J., Duffy, Brian T., Heitzman, Diana L., Lojpersberger, Jeff L., Mosher, Elizabeth A., Novak, Margaret A. 2015. Lower Esopus Creek Stream Biological Assessment.

Action (i.e., velocity, depth). To compare the future without and with the Proposed Action, five fish species groups were selected for HSI analysis. These fish were selected based on the representation and dominance of these species along lower Esopus Creek (i.e., frequency of occurrence and abundance at fish sampling stations), as well as the availability of necessary life history data appropriate for HSI development. The species selected represent forage fish, panfish, and game fish documented to occur in lower Esopus Creek. HSI reports published by U.S. Fish and Wildlife Service describe life history attributes, habitat preferences and physiological limits for selected species. Other conditions that can affect aquatic habitat, such as woody debris and undercut banks, are described in the assessment qualitatively since quantitative data were not available.

As described above, valley reaches were grouped based on similar variations of streamflow, temperature, and turbidity levels. The potential benefits and impacts of the Proposed Action on aquatic resources were assessed according to valley reach and the presence of similar fish species.

In summer 2018, a site survey of SAV beds was conducted for the Esopus Estuary, located downstream of the Cantine Dam, to delineate the presence and extent of SAV beds. Results of the survey were compared to prior studies and aerial imagery to identify changes in the SAV beds.

WETLAND RESOURCES

For lower Esopus Creek, wetlands potentially occurring within the study areas were identified through previous studies, and a desktop evaluation of NYSDEC freshwater wetlands maps and U.S. Fish and Wildlife Service (USFWS) National Wetland Inventory (NWI) maps. Wetland acreage was measured during field surveys conducted between 2009 and 2018 for 49 wetlands upstream of the spillway confluence, ten wetlands downstream of the spillway confluence and 11 floodplain forest transects under various streamflow conditions. Vegetative composition of the wetlands and tree counts were also evaluated during these time periods. Vegetation data were collected using wetland sample plots following the protocol outlined in the USACE Northcentral/Northeast Regional Supplement, Version 2.0 (2012)[34] to document changes in the wetland vegetative communities as part of baseline conditions. Field monitoring events involved visiting the established 11 floodplain forest sample sites, which consisted of two or more transects with plots spaced every 50 feet extending from the bank of lower Esopus Creek to the study area boundary. Tree data collected included diameter at breast height (dbh), species identification, and distance to plot center. Tree data were collected using the point-centered quarter method. Floodplain forest communities were evaluated based on forest structure metrics (mean basal area, mean tree area, stand density) and forest composition (i.e., species richness, Shannon's diversity and equitability indices, Simpson's diversity index, and species-specific relative density and abundance). Observations made during field visits were used to qualitatively predict anticipated changes in relative abundance of dominant species, relative species composition, and overall extent between the future without and with the Proposed Action.

[34] Wakely, J.S. R.W. Lichvar, C.V. Noble, and J.F. Berkowitz. 2011. Regional Supplement to the Corps of Engineers Wetland Delineation Manual: Northcentral and Northeast Region (Version 2.0). U.S. Army Corps of Engineer Research and Development Center.

VEGETATION AND WILDLIFE RESOURCES

Federal/State Threatened and Endangered Species and State Species of Special Concern

Geospatial data, such as the 2011 National Land Cover Dataset, were used to identify broad habitat characteristics of the study area. Federal/State Threatened and Endangered Species and State Species of Special Concern within the study area were identified in consultation with U.S. Fish and Wildlife Service (USFWS) and NYSDEC's New York Natural Heritage Program (NYNHP) (correspondence dated May 9 and 10, 2018).

The NYNHP identified the species and/or habitats with State, heritage, and global rankings based on species rarity, population trends, and threats, along with other information related to the species.

The USFWS Information for Planning and Consultation (IPaC) system was consulted, in accordance with the Endangered Species Act of 1973 and Fish and Wildlife Coordination Act of 1934, and provided an online report of any federally listed Threatened, Endangered, and Candidate Species, or species proposed for listing along with Critical Habitats known to exist within the study area counties.

The assessment of the federal and State-listed species identified as potentially occurring in the study area consisted of estimating any temporary, indirect, or direct effects to the habitat or life history of the species based on anticipated differences between the future without and with the Proposed Action in the lower Esopus Creek study area.

KENSICO RESERVOIR STUDY AREA

AQUATIC (BENTHIC AND FISH) RESOURCES

Benthos and sediment samples previously obtained at the CATIC Cove were used to assess the potential for impacts to benthic organisms from increased deposition of alum due to the delay of dredging and environmental considerations associated with dredging. Similarly, bathymetric surveys in the area of historical alum deposition were reviewed. Sampling and survey data were used with OST to estimate the potential areal extent and depth of alum floc deposition from additional alum application during the RWBT shutdown.[35] A literature review was also conducted. The assessment addresses the impact of the delay of dredging, environmental considerations associated with dredging activities on benthic invertebrates, and the recovery potential for species.

Previous fish surveys and literature were reviewed to assess the potential for impacts to fish from potential increased deposition of alum floc in Kensico Reservoir due to the delay of dredging and environmental considerations associated with dredging. The potential physical effects of dredging on food web relationships, feeding and growth for different fish species, and life stages caused by exposure to aluminum were evaluated. Fish sampling was conducted in August 2006 to assess fish distribution throughout Kensico Reservoir. This survey data, along with existing NYSDEC fish survey data, and a detailed review of available water quality data (pH, conductivity, dissolved oxygen) were used to assess potential impacts to fish. Potential changes to food web relationships were considered in terms of effects on life stage food resources, the potential for aluminum toxicity, and the ability of these species to utilize alternative prey. The assessment addressed the impact of the delay of dredging, environmental considerations associated with dredging activities on fish, and the recovery potential for species.

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[35] The RWBT shutdown is discussed in the Water for the Future Shutdown System Operations section of DEP's Upstate Water Supply Resiliency EIS.

5.3.9 HAZARDOUS MATERIALS

The hazardous materials assessment consisted of identifying the potential for the Proposed Action to increase the exposure of people or the environment to hazardous materials, and whether this increased exposure would result in a potential significant impact to public health or the environment.

The hazardous materials impact assessment for lower Esopus Creek and Kensico Reservoir study areas consisted of: (1) describing baseline conditions by identifying the presence of contamination located adjacent to each waterbody based on a desktop assessment of publicly available federal and State environmental databases; (2) identifying any upcoming proposed projects within the study area; and (3) analyzing the potential for short- and long-term impacts from the Proposed Action that may result in changes in exposure to hazardous materials within the surrounding study areas.

The potential for hazardous materials effects was assessed using the following publicly available environmental databases:

- Federal Databases and Records
- National Priority List (NPL) / Superfund Database
- Environmental Justice Screening and Mapping Tool (including information on Toxic Releases, Waste Discharges, Brownfields and EPA Envirofact)
- New York State Databases and Records
- Spill Incident Database
- Environmental Site Remediation Database
    - State Superfund Sites
    - Brownfield Cleanup
    - Environmental Restoration
    - Voluntary Cleanup
    - Inactive Hazardous Waste Disposal Sites Registry
    - Institutional and Engineering Control
- Bulk Storage Program Database – (Underground Storage Tank [UST] and Aboveground Storage Tank [AST])
    - Petroleum Bulk Storage
    - Chemical Bulk Storage
    - Oil Storage Facility listings
    - Landfill - Solid Waste Management Facilities Map

Additionally, to evaluate the potential for incremental impact along lower Esopus Creek, the results of the database search were reviewed against information collected from Section 7.1, "Water Resources and Water Quality" assessment for the lower Esopus Creek study area to determine whether identified hazardous materials sites would be co-located with areas where there would be differences in potential inundation or erosion between the future without and with the Proposed Action.

5.3.10 INFRASTRUCTURE AND ENERGY

The infrastructure assessment identified the potential for the Proposed Action to result in changes to conveyance and demand for water and sewer infrastructure, including municipal drinking water intakes, sewer discharges, drinking water wells, and septic systems.

The infrastructure impact assessment consisted of: (1) identifying and mapping existing municipal drinking water intakes or sewer discharge locations, including wells and septic systems, within each study area based on a review of State and local databases; (2) identifying any upcoming proposed projects within the study areas that have the potential to result in changes to conveyance and demand for water and sewer infrastructure; and (3) analyzing potential short- and long-term changes due to the Proposed Action to water and sewer infrastructure such as municipal drinking water intakes, sewer discharge locations, drinking water wells, or septic systems within the study area as compared to the future without the Proposed Action.

Energy use is not anticipated to change in the lower Esopus Creek study area as a result of operation of the Ashokan Release Channel. An energy assessment at the Kensico Reservoir study area was conducted. This assessment consisted of qualitatively assessing the potential for the Proposed Action to result in changes of energy generation or demands or distribution within the surrounding study area due to the delay of dredging, and environmental considerations associated with dredging and dewatering activities at Kensico Reservoir.

5.3.11 TRANSPORTATION

A transportation assessment examines the potential effects of a proposed project on the transportation system, including the analysis of potential traffic, pedestrian, parking, and safety impacts. Vehicle trips that would be associated with operation of the Ashokan Release Channel within the lower Esopus Creek study area would be minimal. In addition, the Proposed Action within the lower Esopus Creek study area would not generate additional parking demand or substantially change pedestrian traffic flows in the study area. The traffic analysis for the Kensico Reservoir study area consisted of: (1) identifying and describing the roadways within the study area; (2) identifying any upcoming proposed projects that have the potential to result in changes in land use or increases in traffic within the study area; and (3) analyzing the potential for short-term changes by determining if the delay of dredging or environmental considerations of dredging would generate significant increases in vehicle trips from workers and equipment. The Proposed Action within the Kensico Reservoir study area would not generate additional off-site parking demand or substantially change pedestrian traffic flows to warrant a parking, pedestrian, or accident analysis.

5.3.12 AIR QUALITY

An air quality assessment examines the potential effects of a proposed project on ambient air quality, as well as the effects of ambient air quality. There would be no new stationary or significant mobile air emission sources associated with the operation of the Ashokan Release Channel. Vehicle trips that would be associated with operation of the Ashokan Release Channel within the lower Esopus Creek study area would be minimal.

The impact assessment for the Kensico Reservoir study area included: (1) describing conditions within the study area by identifying existing local ambient air quality using the nearest monitoring station(s) based on the NYSDEC's EPA-approved air monitoring network; (2) identifying any upcoming proposed projects within the study area that have the potential to affect local air quality; and (3) qualitatively assessing the potential for short-term changes by determining if the delay of dredging or environmental considerations of dredging would generate significant air quality emissions from stationary and/or mobile sources.

5.3.13 NOISE

A noise assessment examines a proposed project's potential effects on sensitive noise receptors, including the effects on the level of noise inside residential, commercial, and institutional facilities, and at open spaces, and the effects of ambient noise levels on new sensitive uses introduced by the proposed project. There would be no new stationary or significant mobile noise emission sources associated with operation of the Ashokan Release Channel. Vehicle trips that would be associated with operation of the Ashokan Release Channel within the lower Esopus Creek study area would be minimal.

The impact assessment for the Kensico Reservoir study area consisted of: (1) describing baseline conditions within the study area by identifying existing noise levels in the immediate vicinity of the dredging and dewatering activities and determining if noise-sensitive receptors would be located within 1,500 feet; (2) identifying any upcoming proposed projects that would result in a change in land use or new noise-generating sources that have the potential to increase ambient noise levels within the study area; and (3) qualitatively assessing the potential for short-term changes to noise by determining if the delay of dredging and environmental considerations associated with dredging would generate significant increases in noise levels from stationary and/or mobile sources.

5.3.14 GREENHOUSE GAS EMISSIONS AND CLIMATE CHANGE

There would be no significant generation of greenhouse gases in the future with the Proposed Action.

As stated in Section 5.2.1, “Analysis Approach – Climate Change Considerations,” the OST hydrologic record was extended to include available data through 2017 in response to comments received during the National Academy of Science's preparation of *Review of the New York City Department of Environmental Protection Operations Support Tool for Water Supply* (2018). As a result, the hydrologic record used to conduct modeling for the EIS considered a wide range of precipitation and climate events that could occur at any point, or in any year, and also considered historical peak storm events, droughts, and recent years. As described in Section 5.2.1, “Analysis Approach,” observed streamflow over the past 30 years was found to be similar to observed streamflow for the middle 50th percentile of years or ‘normal years’ of the OST period of record. The wet years served as a proxy for evaluating potential effects of the Proposed Action taking into consideration climate change. Therefore, the EIS evaluates the long-term potential for incremental impacts in the future with the Proposed Action due to climate change (see Section 7.1, “Water Resources and Water Quality”). Additionally, the IRP, as written, provides the flexibility to make modifications, as needed, to respond to changing hydrologic and operational conditions.

5.3.15 PUBLIC HEALTH

The public health assessment consisted of identifying the potential for the Proposed Action to result in changes that could alter the elements that comprise public health, such as water quality in Kensico Reservoir and lower Esopus Creek. Environmental considerations of dredging, including air quality, hazardous materials, or noise at Kensico Reservoir were also identified.