Stream Gradient and Knickpoint Development and Evolution of the Plotterkill Creek, Rotterdam, New York

By

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ABSTRACT

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The Plotterkill Nature Preserve of Rotterdam Junction, New York represents a deeply-incised stream channel and contains a variety of geomorphological landforms, including two prominent knick points, cascading waterfalls, landslides, strath and fill terraces, and large bedrock exposures caused by incision following deglaciation in New York. Data were collected using a TruPluse laser rangefinder and basic surveying methods, totaling a distance of 5,240 meters and an increase in elevation of 196 meters from the confluence of the Mohawk River to the edge of the preserve, producing an average stream gradient of 0.0365.

Following the retreat of the Laurentide Ice Sheet from ca. 18,000 to 13,000 yr B.P., many proglacial lakes formed and deposited sediments, including Lake Albany (Hudson Valley) and Lake Iroquois (Mohawk Valley) which were connected by the Iromohawk Channel. Based on radiocarbon dating and topographical elevations, it is estimated the Iromohawk River incised approximately 35 meters in the Plotterkill Area in the last 13,500 years as lake levels dropped, 20 meters of which likely occurred prior to 12,900 yr B.P. as the Ballston Channel was abandoned. The Plotterkill stream gradient evolved as a direct result of these base level drops, while knick point evolution based on stratigraphic evidence indicates an average headward erosion of may be on the order of approximately six cm/yr.

ACKOWLEDGEMENTS

First and foremost I would like to thank Dr. John Garver for all his excitement, patience, time, and effort throughout the duration of this project and my tenure at Union College. I would also like to thank the entire Geology Faculty at Union, especially Jaclyn Cockburn, for their assistance and time in helping me complete this study. They have helped mold me into the geologist and person I have become through the past four years. I extend special thanks to all the people who spent their time (and risked their safety) collecting data with me throughout the Plotterkill, especially Rosalba Quierlo, Tiffany Allaway, Cathy Barrows, Ashley Kovack, and Megan Kaknis. And finally, I would like to acknowledge my parents, Donald and Cathy Barrows, and Robert Kielb, for always providing support and help throughout my college years. Without any of these people, this project would not have been possible.

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INTRODUCTION

The Plotterkill Nature Preserve of Rotterdam Junction, New York (Schenectady, New York) consists of 632 acres (~256 hectares) of coniferous and hardwood forests along the Plotterkill, a north-flowing tributary of the Mohawk River. Included in the preserve are Rynex Creek, a tributary of the Plotterkill, three major knickpoints (waterfalls) including the Upper and Lower Plotterkill Falls and Rynex Creek Falls, numerous terraces, two spans of cascading waterfalls, an active landslide, and large areas of exposed bedrock. In the preserve to the Mohawk, the Plotterkill Creek has a total length of 5,500 meters and drops in elevation approximately 200 meters down from the headwaters to the Mohawk River. Above this section, the gradient is very low and the headwaters are not incised.

The Plotterkill Preserve is underlain by the Schenectady Formation (Ordovician), which is composed of interbedded greywacke sandstone and shale varying in thickness. This formation originates from flysch deposition following the erosion of the Taconic Island Arc after the Taconic Orogeny (Garver, 1995). The Schenectady Formation is visible in many localities throughout the Preserve as the stream incises the bedrock and overlying mantle of glacial drift. Despite this exposed bedrock, much of the Preserve contains surficial deposits including glacial drift, glacial till, talus and colluvium, and fluvial sand and gravel (Rodbell and Hays, 1995).

The geomorphic features in the Plotterkill Creek formed following deglaciation of the area and the progressive drainage, reorganization, and base level lowering in the past 13 ka. The presence of fluvial terraces in the preserve represent paleofloodplains and how the modern floodplain has changed through time. Base level has been progressively dropping for the last 12 ka as the Mohawk River has meandered, incised, and altered its course.

This study begins with the surveying and mapping of the Plotterkill Creek. These data are then used to construct a longitudinal stream profile that shows the stream gradient. Following this data analysis, the development of the local drainage basin (catchment) through time is investigated. This analysis includes looking at how the sediment load moves through the system and how erosion is proceeding in the Plotterkill.

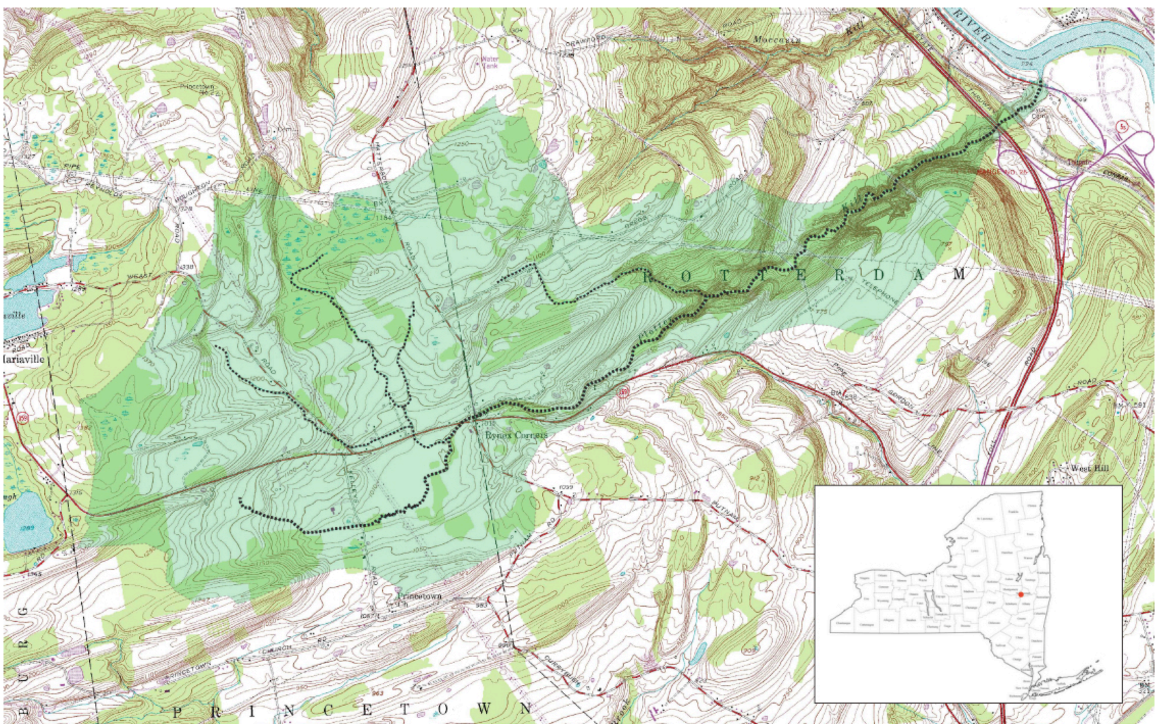

Figure 1: The Plotterkill Creek drainage basin, Rotterdam, New York (USGS Rotterdam Junction Topographic Map). This study focuses on the stream gradient of the deeply-incised part of the creek from the Mohawk River to slightly downstream from Rynex Corners.

GEOLOGIC BACKGROUND

The Plotterkill Nature Preserve is located approximately 10 kilometers northwest of Schenectady, New York. This preserve contains 632 acres (~256 hectares) of rugged hardwood and coniferous forests along the Plotterkill, which is a tributary of the Mohawk River. Also included in the Preserve is Rynex Creek, a tributary of the Plotterkill. There are three major waterfalls, including the Upper Falls, the Lower Falls, and the Rynex Creek Falls at the junction of Rynex Creek and the Plotterkill, cascade waterfalls, up to three prominent fluvial terraces, an active landslide, and large areas of exposed bedrock. The Plotterkill drops 900 feet in elevation and is 3.5 miles long from Rynex Corners to the Mohawk River, but for this project only 5400 meters were measured with a drop of 200 meters in elevation (See "A Guide to the Plotterkill Nature and Historic Preserve").

Rotterdam, New York lies in the Northeastern United States, an area with a humid, temperate climate. This region is known to undergo periods of extreme temperatures in the summer and winter, including periods of flooding and drought. On average, Rotterdam receives approximately 63 cm per year of precipitation. Vegetation can vary throughout the region, but the Plotterkill Nature Preserve changes and you drop in elevation and move towards the Mohawk River. At the top of the valley, there are flat plains, moving into deciduous hardwoods common in New York. As elevation decreases, there becomes a stronger presence of coniferous hardwoods. As both the northeast and southwest ends of the creek, wetlands can be observed.

The Plotterkill Preserve in underlain by the Schenectady Formation (Ordovician), which is composed of interbedded greywacke sandstone and shale (Garver, 1995; Rodbell and Hays, 1995). The origin of this formation is believed to be from turbidite deposition during the erosion of the Taconic island arc (Garver, 1995). While the Schenectady Formation is visible in many localities throughout the Preserve as the stream incises the bedrock and overlying mantle of glacial drift, much of the Preserve contains surficial deposits including glacial drift, glacial till, talus and colluvium, and fluvial sand and gravel (Rodbell and Hays, 1995).

The fluvial terraces along the valley floor of the Plotterkill are underlain by poorly sorted deposits of sand, gravel, and angular boulders up to 70 cm long that were derived locally from the sandstone beds of the Schenectady Formation (Rodbell and Hays, 1995). These sediments are believed to be deposited by fluvial processes because they display a pronounced imbrication in which their a-b axis are inclined upstream, which was observed during the course of this fieldwork.

Fluvial terraces represent the remains of paleofloodplains. For a floodplain to develop, a period of equilibrium is required between the sediment yield and the stream power (Ritter et al., 1995). It is during this time that the channel neither aggrades or degrades, but produces a broad, flat valley floors beveled on bedrock or alluvium as fluvial erosion is dominantly lateral (Rodbell and Hays, 1995). As the stream power increases and/or the sediment yield decreases, the stream will incise into the floodplain. These terraces indicate that the rate of incision of the Plotterkill has not been constant since the retreat of glaciers because locally sediment had built up.

Rodbell and Hays suggest that at least some of the terraces in the Plotterkill are erosional (strath) terraces rather than depositional. This is based on the observation of the boulder lag of sandstone underlying the terraces has a thickness less than two meters in several locations and rests on a horizontally beveled planar surface on shale of the Schenectady Formation shale. The observation that the Plotterkill terraces are unpaired also supports this idea, as unpaired terraces are associated with lateral and vertical erosion rather than deposition (Ritter at al., 1995). Strath terraces depict progressive fluvial incision with periods of equilibrium.

This progressive fluvial incision by the Plotterkill could be caused by a number of factors, including a decrease in local baselevel (Mohawk River), a decrease in sediment yield, and/or an increase in stream power. After deglaciation of this region, progressive drainage of Glacial Lake Albany ca. 13-12 ka and the incision of the Mohawk and Hudson Rivers into the deposits of Glacial Lake Albany that followed would have lowered the local base level (Rodbell and Hays, 1995). This, in turn, affected tributary streams, causing them to incise as well. Along with the terraces observed at the Plotterkill Preserve, Washout Creek, a tributary of the Mohawk River north of the Plotterkill, has three prominent terraces, suggesting that fluvial incision in the eastern Mohawk Valley is a regional phenomenon and may have been caused by the progressive drainage of Glacial Lake Albany (Rodbell and Hays, 1995).

METHODS

The main objective of measuring the Plotterkill Creek using basic surveying methods was to measure and construct a precise longitudinal stream profile through stream bed inclination and horizontal distance. Along the length of the Plotterkill Creek, any changes in the surrounding area were observed and noted with their distance upstream in meters, including sediments in and around the stream channel, bedrock exposures, waterfalls, debris shoots, land instability, terraces, and any other abnormalities.

The stream gradient and length of the Plotterkill were measured through the use of a TruPulse laser, reflective lens, tri-pod, reflective target, and target stand. Before any data could be collected, the reflective target was placed at the same height at the laser lens to assure correct inclination measurements. Beginning with the point where the Plotterkill enters the Mohawk River, data were collected by two people moving upstream. The distances measured ranged from 1.8 meters to 123 meters, but on average, the measured distances were ~40 meters. The individual with the laser and reflective lens on the tri-pod stood in the stream where the water flow was at its peak, while the individual with the reflective target and stand moved upstream. The horizontal distance between the two points was dependant on any changes in stream flow, including meandering, and interference of a clear shot, including trees, plants, or sudden changes in gradient such as waterfalls or plunge pools. In these situations, shorter measurements were taken to assure continuous distance and inclination.

While the TruPulse laser rangefinder was extremely helpful in collecting data, there were some difficulties with the measurements. The waterfalls were extremely difficult to measure as some of the plunge pools were rather deep and deciding where to start that measurement, either in the pool or before the pool, varied with the location. Another problem encountered occurred after periods of precipitation. The increased stream flow made it difficult to walk in the stream without getting injured, as the bedrock and sediments were extremely slippery when wet. High flow made it difficult to decide where the channel center was.

Once the person with the laser and the person with the target agreed on a distance, the laser was shot directly at the reflective target and measurements were produced through the viewfinder. Each measurement included horizontal distance, azimuth, and inclination; the horizontal distance and inclination were recorded in a field notebook in meters and degrees, respectively. At many measurement site, a Garmin GPS receiver was used to collect a waypoint consisting of latitude and longitude, along with observations to the east and west of the stream, including terraces, sediment, clast size, and visible bedrock (Appendix A). Once this measurement and observations were collected, the person with the target left a marker of their exact location so the shooter can measure again from that exact spot creating a continuous measurement.

After collecting the horizontal distance, inclination, and observations of the entire Plotterkill, the data were placed in a Microsoft Excel spreadsheet to be processed (Appendix B). This included changing degrees to radians in the Excel spreadsheet, so that the angle could be converted to a vertical distance in meters. A profile of the Plotterkill was then constructed from the rise and run calculated

DATA

Data in this study were collected throughout the stream valley at the Plotterkill Nature Preserve in Schenectady County, New York. The Preserve contains 632 acres (~256 hectares) of rugged hardwood and coniferous forests along the Plotterkill stream, a tributary of the Mohawk River (See "A Guide to the Plotterkill Nature and Historic Preserve, Schenectady County"). Data include inclination of the stream gradient and horizontal distance. At each site, careful observations were recorded, including the presence or terraces, bedrock, landslides, or slope instability, clast size, imbrication of sediment, and washout debris.

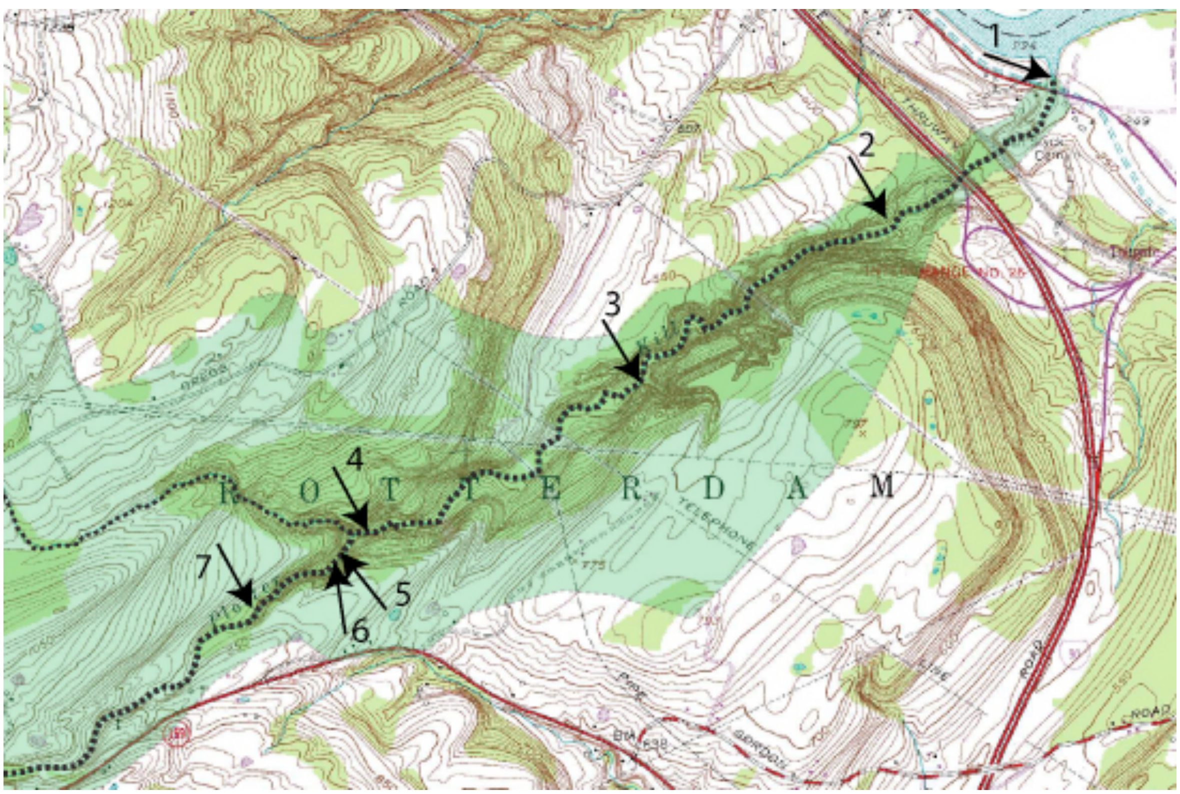

Figure 2. Topography of the Plotterkill Nature Preserve with the start point of each section marked with an arrow and corresponding section number (USGS Rotterdam Junction Topographical Map).

This section of the Plotterkill was measured using 132 station points. The measured section is 5,240 meters long, with an increase in elevation of 196 meters from the base of the Mohawk River to the edge of the preserve. With the data collected, a stream gradient profile was created which yielded an average slope of 0.0365 (Figure 3).

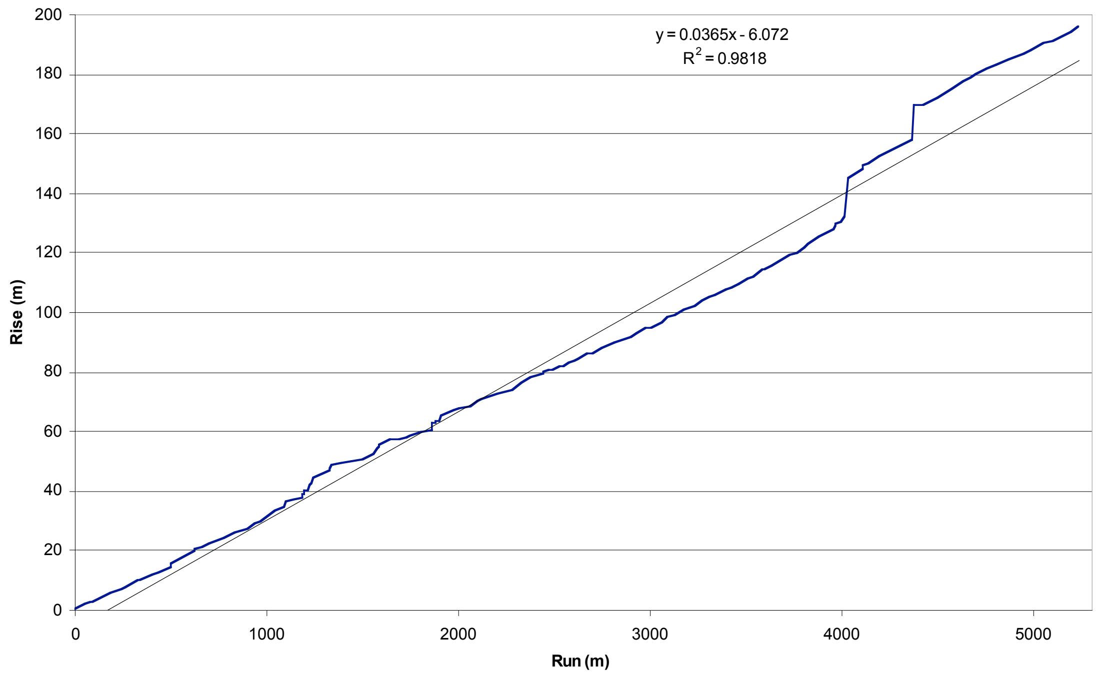

Figure 3. Longitudinal profile of the Plotterkill stream gradient, Schenectady, New York. This profile was measured using 132 stations and distance was measured using a TruPulse laser rangefinder.

The geomorphology of the area surrounding the Plotterkill creek is variable. Landforms include exposed bedrock, waterfalls, cascade waterfalls, landslides, and sediment fill with terraces. The Plotterkill stream bed can be divided into seven portions with distinctive landforms and topographical breaks. These include the following: (1) from the Mohawk River to approximately 1140 meters; (2) from 1140 meters to 2400 meters; (3) from 2400 meters to the lower Plotterkill falls; (4) the Lower falls; (5) between the Lower and Upper Plotterkill falls; (6) the Upper falls; and (7) the remaining area following the upper falls. These sections are briefly described below.

Section 1: 0-1140 meters

The first portion of the Plotterkill begins at the confluence of the Mohawk River moving upstream about 1140 meters where area surrounding the stream changes from high amounts of sediment to exposed bedrock and small waterfalls. Because this section is near the river and many transportation crossings (Railroad, Interstate 90, Route 5s), it was difficult to collect meaningful measurements of the length and gradient as there were three bridges that cut across the creek. Ultimately, these transportation crossings affected the terraces measured because the concrete interrupted continuous stream flow and changes the landscape of the area. Despite these potential issues, the stream gradient has a slope of 0.0318 (Figure 4), which is similar to gradients upstream. The small jumps in the longitudinal profile were caused by the drop-offs from the tunnels as data were collected.

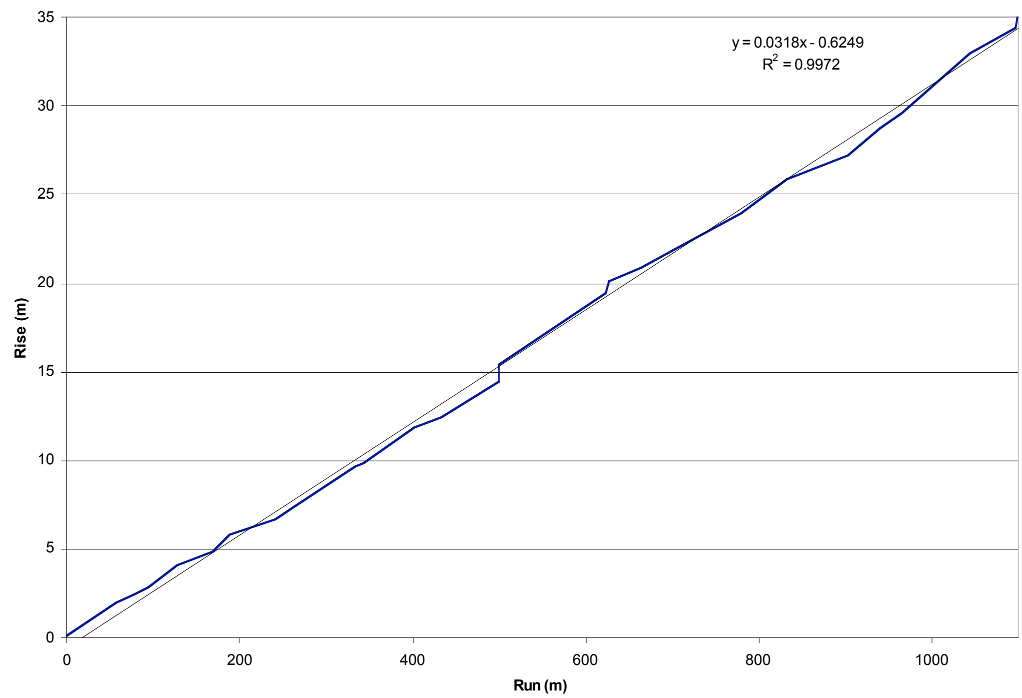

Figure 4. Longitudinal stream profile of the Plotterkill from the Mohawk River to the small falls, approximately 1140 meters upstream (Section 1).

Beginning at the mouth of the Mohawk River, the Plotterkill stream channel is rather wide (approximately seven meters) with sediment comprised of smaller clast sizes ranging from 0.5 cm to eight cm on both sides of the channel for the first 100 meters. The first of the three bridges were encountered, with a small pool downstream of the tunnel and small cobbles sitting upstream of the tunnel. Following the Rt. 5s tunnel, the channel is rather flat and wide again, with a range of smaller clast sizes ranging from one cm to ten cm in and around the stream. At 241 meters, the first large cut bank was observed, exposing soil containing rounded pebbles and cobbles, which was believed to be glacial outwash, with small terraces to the east and west. These terraces continue to the 59 meter long train tunnel that cuts across them, altering the landscape. A small plunge pool occurs below of the drop-off of the tunnel as the concrete ended and the stream flowed downstream, along with small terraces to the east and west. The portion of the stream that stretches from 265.9 meters to 624.8 meters is a difficult area to measure and collect observations, as it contains the train tunnel and the 123.5 meter long tunnel from the New York State Thruway. No prominent landscapes were observed as they were altered from building these bridges. Measurements were made shooting the TruPulse laser through the tunnels, so there is no break in the data.

Moving upstream following the NYS Thruway, there are many large boulders, as well as small cobbles, present in the stream channel and on the flood plain, ranging in size from 0.1 meters to two meters, many of which appear to be exotic metamorphic clasts likely from the Adirondacks (i.e. they are not from the Schenectady Formation). Some minerals observed in these boulders included hornblende, garnet, plagioclase, and quartz. The remaining 525.8 meters of the channel in this section is broad and sediment-filled. The stream meanders, commonly bifurcating with clear and distinct benches of sediment between channels. There are many cut banks from the meandering stream, exposing underlying sediments (of unknown origin) as the stream cut into the terraces exposed along sides of the creek. At approximately 1100 meters, the area surrounding the Plotterkill consists of steep sloped hills that were unstable for 36 meters, but then change to possibly three small terraces to the east and west of the stream (Figure 5).

Figure 5. An unstable bedrock slope in the Plotterkill Nature Preserve, approximately 1100 meters upstream.

Section 2: 1141 m- 2451 m

The second section of the Plotterkill extends from 1140.6 meters to 2451.0 meters and is comprised of exposed bedrock and small waterfalls, including two spans of cascading waterfalls (Figure 6). These waterfalls were measured in small portions (approximately 10-20 meters horizontally) from step to step to create a more accurate longitudinal profile.

Figure 6. Cascading waterfall of the Plotterkill, approximately 1220 meters upstream.

The stream gradient of this section was 0.0313, but unlike the previous section, the average longitudinal profile deviates considerably from the actual stream profile because there are many small bedrock knickpoints (Figures 6, 7).

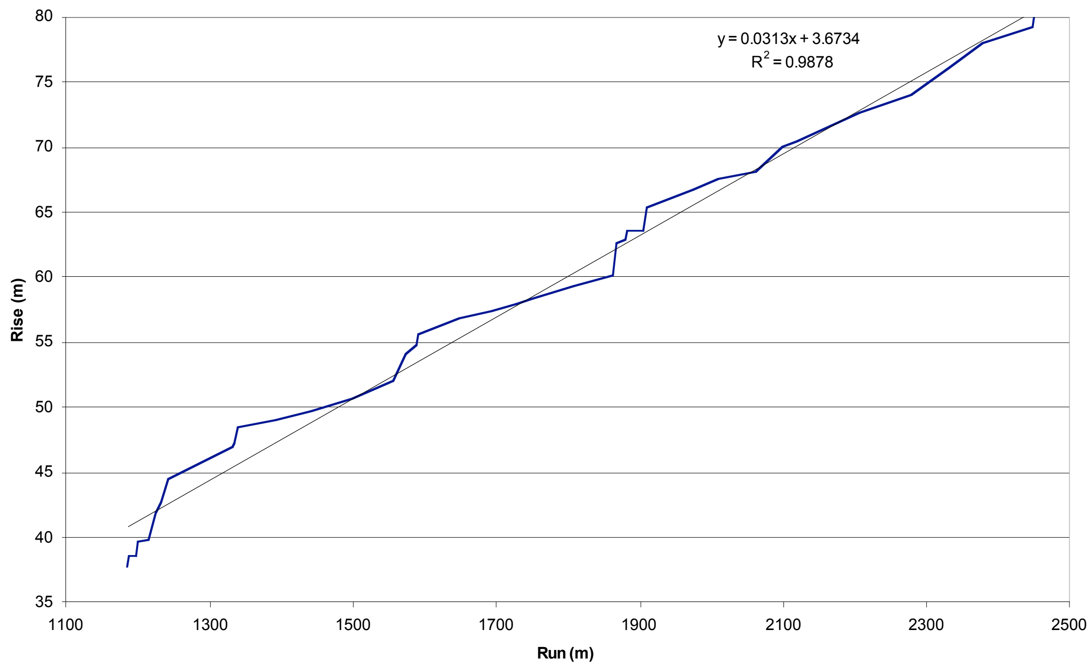

Figure 7. Longitudinal stream profile of the Plotterkill from 1140 meters to 2451 meters (Section 2).

In section two, from 1140.6 meters to 2061.7 meters, the stream channel changes from sediment and terraces to bedrock and small waterfalls. The stream has a bedrock base (floor) as well as bedrock to the sides of the stream. The portions of the stream from 1140.6 m to 1340.8 m, and 1574.7 m to 1905.0 m formed “steps” or cascading waterfalls, as observed in Figure 7. Both of these stretches contain very little sediment in the stream and the channel mostly lies in bedrock. At approximately 1392.9 m, there is a large drainage shoot that introduced washout sediment of larger clasts from the surrounding slope to the stream (1392.9 m to 1558.1 m). The second area of cascading falls wraps around the exposed bedrock to the west and collectively stands approximately 9.5 meters high with a 1.3 meter deep plunge pool.

Following these cascading falls is an area of smaller falls that are generally more spread apart rather than forming clear, close-spaced steps. Small sediment terraces are present from 1694.5 m to 1809.3 m, but they are minor, and another minor set occurs from 2101.5 m to 2121.5 m where the west slope is steep with drunken trees. This section is followed by a 15-18 meter high wall of bedrock to the east and a five meter tall wall to the west. Towards the end of this section, at 2332.4 m upstream, a landslide occurs to the west, introducing loose sediment with a range of clast sizes to the stream channel. This section ends with the reference point called “Sergeant’s Falls”, a V-shaped small waterfall with a steep, bedrock drainage shoot to the east.

Section 3: 2451 m to 3965 m

The third section of the stream begins at 2451.0 meters and continues to 3964.8 meters. This section has a relatively steady slope and is largely sediment-filled. This section is crossed by the public utility transmission lines above and a gas pipeline below ground. Throughout this section, there is very little bedrock exposed, a large amount of sediment in the stream channel, and has a number of terraces east and west of the stream. The stream slope measured 0.0315 while the longitudinal stream profile correlates well with the trend line (Figure 8).

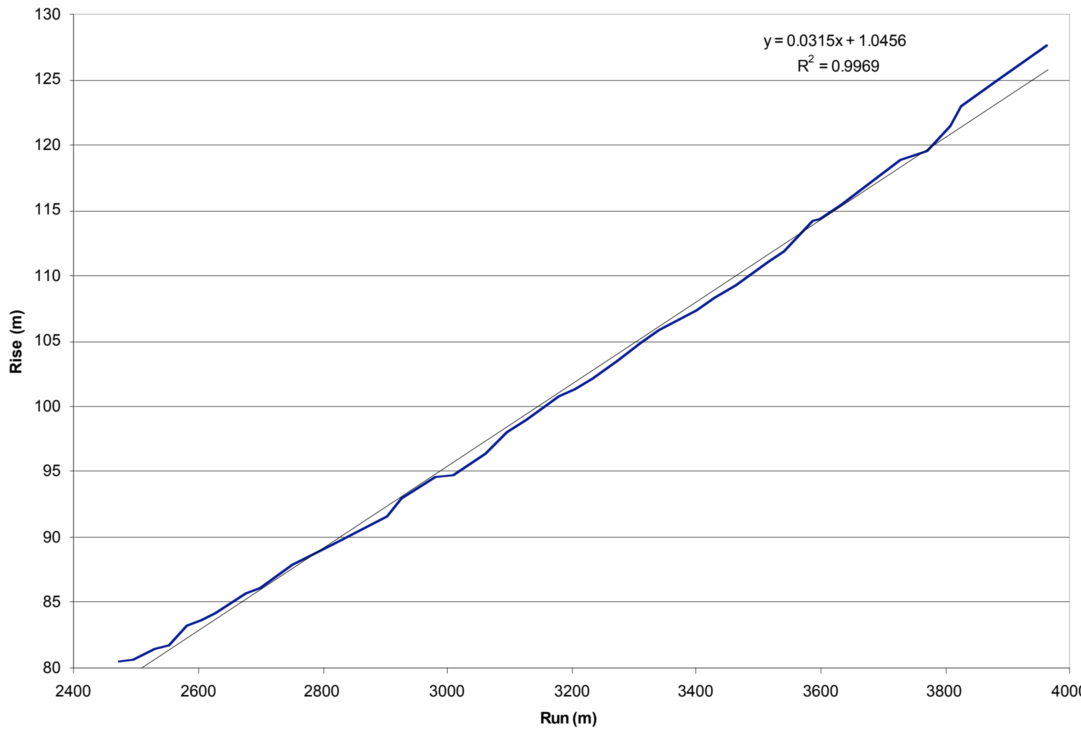

Figure 8. Longitudinal stream profile of the Plotterkill from 2451.0 m to 3964.8 m upstream.

Upstream from "Sergeant's Falls" prominent terraces are visible east and west of the stream which continue for long stretches, including from 2553.1 m to 2582.9 m and from 2816.3 m to 2903.4 m. At 3181.7 meters, there was a large washout dam with many trees, branches, and larger clast size sediments blocking the channel. This location was directly in the public utility transmission line. Slightly past this location, a man-made stone wall was observed, with possible terraces farther away from the stream. At 3276.8 m, at least two terraces were observed to the east, which correlates with many of the terraces seen in this portion along the east side of the stream. Approximately 20 meters downstream, another dam due to washout was observed and formed a pool, slowing the flow of the stream. As the end of this section was approached, the terraces became less obvious and bedrock re-appears as the surrounding landform of the Plotterkill.

Section 4: Lower Plotterkill Falls (4017.4 meters to 4109.4 meters)

Following this terrace and sediment-filled portion of the stream is the Lower Plotterkill Falls. Initially, there is a two meter tall cascading falls split into two main steps (Figure 9).

Figure 9. The cascading waterfall below the Lower Plotterkill Falls at 3973.0 meters upstream.

There is also another small, approximately one meter tall, rectangular cut falls approximately ten meters upstream from the cascading falls (Figure 10).

Figure 10. Small falls with medium-bedded sandstone (approximately 0.25-0.6 m) below the Lower Plotterkill Falls at 4000.1 meters upstream.

This section is underlain by thick beds of sandstone ranging in size from 0.2 meters to approximately one meter. Moving upstream to 4036.5 m is the Lower Plotterkill Falls which stands 13.07 meters in height (Figure 11). As observed in the field and in the figure, the thickness of these sandstone beds ranged from approximately 0.2-0.8 meters, however, there were very few shale beds present.

Figure 11. The Lower Plotterkill Falls of the Plotterkill Nature Preserve at 4036.5 meters upstream.

While this section was relatively short, measuring 136.4 meters, there was an increase in elevation of 19.5 meters. The slope of the longitudinal profile measured 0.154 (Figure 12).

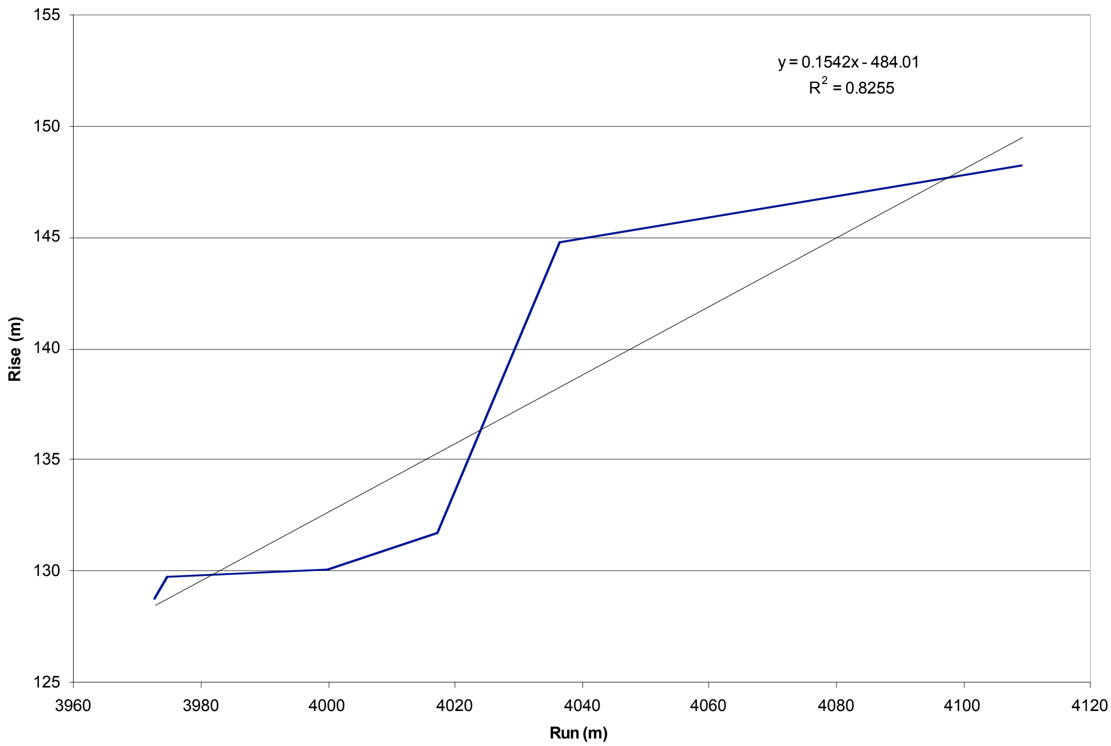

Figure 12. The longitudinal profile of the Lower Plotterkill Falls.

Section 5: Between the Falls

The section of the Plotterkill Creek between the Lower and Upper Falls extends from 4109.4 m to 4316.6 m and is comprised mostly of sediment with terraces present to the east and west. The stream gradient for this section is 0.0342 (Figure 13).

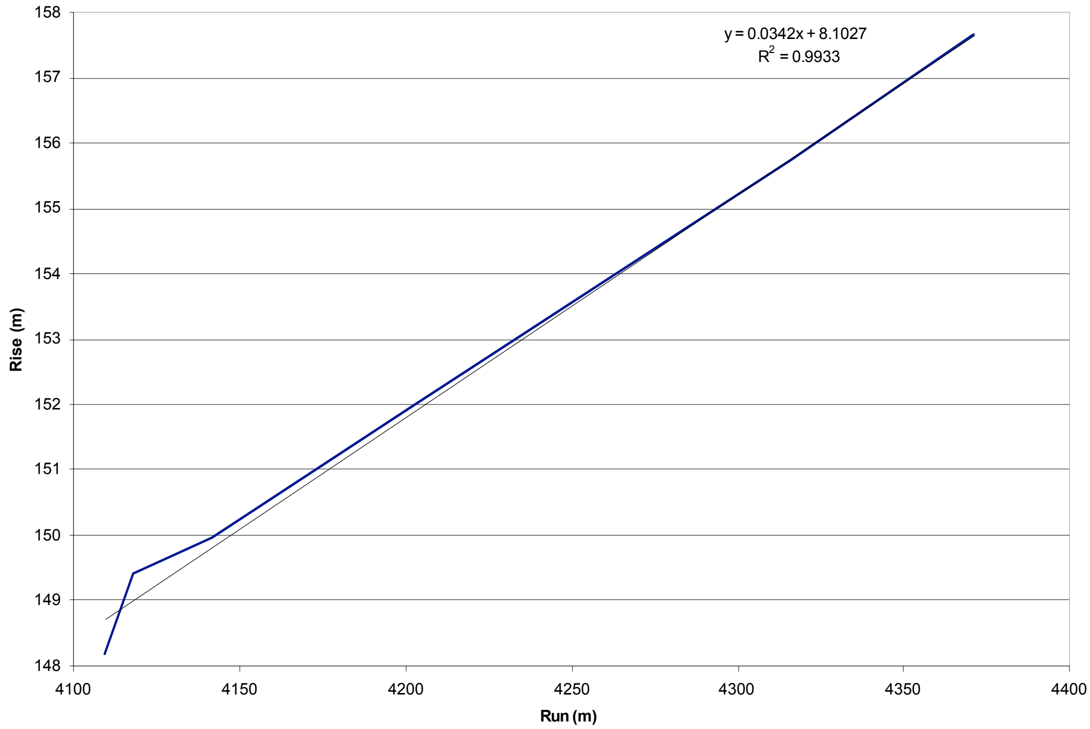

Figure 13. Longitudinal stream profile between the Lower and Upper Falls of the Plotterkill Preserve.

As depicted in the longitudinal profile and Figure 14 below, directly after the Lower Falls is a 24 meter long section of exposed bedrock with an inclination of 8.2 degrees, increasing in elevation 1.2 meters (Appendix A).

Figure 14. Bedrock exposure above the Lower Plotterkill Falls, exposing a bedrock floor and approximately 0.8 m thick sandstone beds.

This bedrock exposure becomes covered with sediment and cobbles upstream, exposing a terrace to the west. As the Upper Falls is approached, there are many cobbles present in the stream channel, and bedrock is exposed on top of the channel slopes to the east and west. This section ends at the ~0.8 meter deep plunge pool of the Upper Falls which contains a large amount of fall sandstone beds and cobbles ranging in diameter from 0.3-1.0 meters.

Section 6: Upper Plotterkill Falls

The Upper Plotterkill Falls was measured using two station points and extended from 4371.3 m to 4381.6 m, with a height of 11.5 meters (Figure 15).

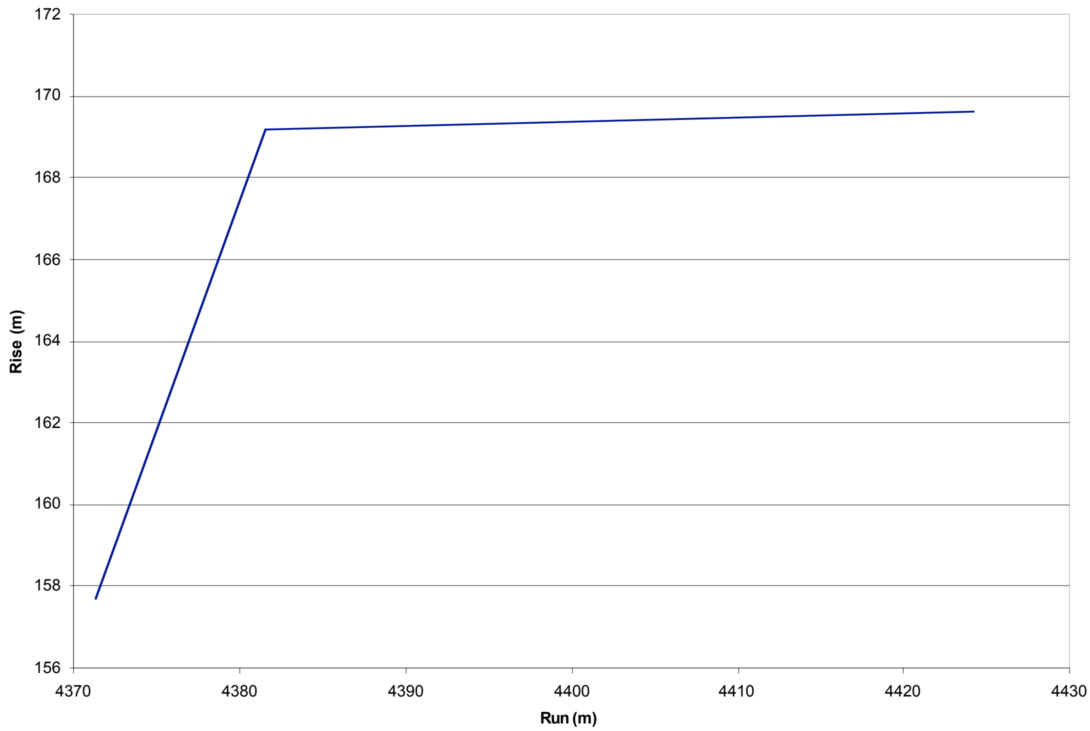

Figure 15. Longitudinal stream profile of the Upper Falls of the Plotterkill Creek.

The Upper Falls is comprised of thick sandstone beds, ranging from 0.4 m to 2.5 m, as observed in Figure 16 below. The thickest beds are at the top of the falls, while the thinnest beds lie at the base of the falls (Figure 17). A large amount of sediment lies at the base of the falls, ranging in clast size from 0.1 m to 1.0 m, many of which are fallen sandstone beds from headward erosion and undercutting due to stream flow.

Figure 16. The Upper Plotterkill Falls of the Plotterkill Creek, 4371.3 m upstream.

Figure 17. Exposed Schenectady Formation to the East of the Upper Plotterkill Falls 4371.3 m upstream. These beds range in thickness from 0.4 m to 2.5 m.

Section 7: Continuing Upstream From the Upper Falls

The last section measured in the Plotterkill Creek extends from the Upper Falls to the southern edge of the Preserve, or 4424.3 m to 5240.3 m. The stream gradient of this portion is 0.0311, which is similar to the gradient of Section 1 (Figure 18). Throughout this section, the stream gradient is constant, has no waterfalls, and there are large spans of exposed bedrock, fill terraces to the east and west, and many large cobbles and boulders. The stream meanders and cuts into the terraces, exposing sediment fill, and leaving abandoned channels possibly used during periods of flooding.

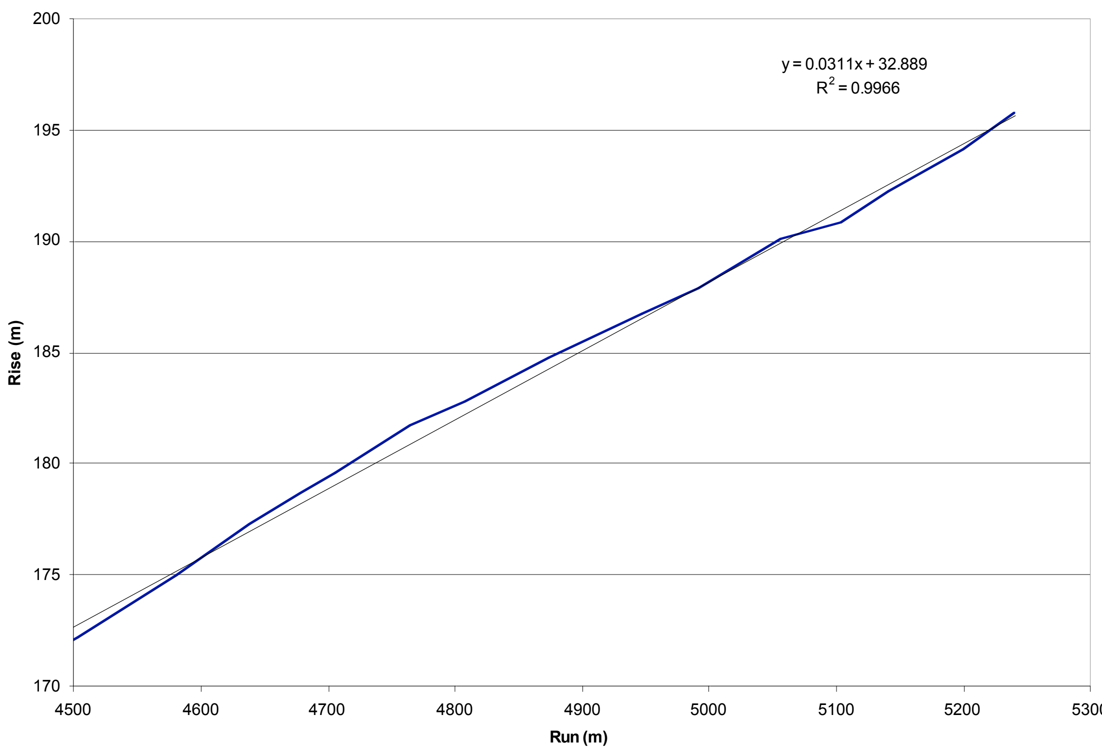

Figure 18. The longitudinal stream profile from the Upper Falls, 4424.3 m, to the southern edge of the Plotterkill Preserve, 5240.3 m.

Beginning at the top of the Upper Plotterkill Falls, the Schenectady Formation is exposed, but becomes covered with sediment, cobbles, and boulders ranging in clast size from 0.1 m to 1.2 m moving upstream. A terrace is exposed to the east while the cobbles and boulders in the stream channel are imbricated to correlate with stream flow. At 4678.5 m, the stream bifurcates and forms a bench in the middle of the channels. To the west, the meandering stream cuts into the fill bank, exposing the underlying shale bedrock (Figure 19).

Figure 19. Exposed shale bedrock of Schenectady Formation with overlying fill terrace approximately 0.8 m in thickness 4678.5 m upstream in the Plotterkill Creek.

The stream continues to meander and cut into the terrace to the west from 4678.5 m to 5056.6 m. This area is very flat and long, the slope is consistent, and no bedrock is exposed. At 5056.6 m, the channel base changes from being covered with sediment and cobbles to exposing the underlying bedrock. Slightly upstream at 5104.4 m, possibly two or three terraces become visible to the west, which continue upstream.

INTERPRETATIONS

Glaciation in New York

Beginning about 80,000 years ago, the last major ice age known as the Wisconsin episode, left a majority of northern North America covered by continental glaciers (Barnes, 2003). At its peak, approximately 20,000 years ago, the Laurentide ice sheet covered some five million square miles from the Arctic Ocean to eastern Canada, New England, and northern half of the U.S. Midwest. The ice front stretched from the Atlantic Ocean to the foot of the Rocky Mountains where it met the Cordilleran ice sheet. Throughout the duration of glaciation, there were numerous advances and retreats of ice lobes, but a general retreat of glacial ice began about 18,000 years ago (Barnes, 2003). These ice sheets retreated to the north, forming ice-dammed lakes along the southern margins and causing catastrophic flooding events (Barnes, 2003). By 7,000 years ago, only small remnants of the Laurentide ice sheet remained, leaving behind a fresh landscape of glacial landforms, proglacial lakes, and reorganized drainages.

In New York, this last major episode of glaciation resulted in ice sheet advance as far south as Long Island. Ice sheets in the Capital District may have exceeded 800 meters in thickness (Barnes, 2003). The advancing ice carried a large amount of rock debris scoured from Canada and the Adirondack Mountains. The ice also eroded bedrock and soil and deposited this mixture of boulders, gravel, sand and clay as glacial till, forming think sediment deposits, terraces, and drumlins. When the Laurentide ice sheet began to thin and recede irregularly northward about 18,000 years ago, water from the melting ice sheets sorted sediments and redeposited them based on clast size; poorly sorted materials were deposited close to the glacier, while well-sorted material was deposited farther away (Barnes, 2003).

Iromohawk System

The Iromohawk System is a general term used here to refer to the three-part system during deglaciation in the Mohawk and Hudson Valleys in New York State. These parts include Glacial Lake Iroquois in the Ontario Basin, the Iromohawk Channel, which existed where the modern Mohawk River lies, and Glacial Lake Albany and the many phases that followed in the Hudson Valley (Figure 20, Kessler, 2007). The Iromohawk channel contained the Iromohawk River, the precursor of the modern Mohawk River (Wall, 1995). This system is essential to examine when determining how deglaciation, meltwater drainage, and base level change effected the formation and evolution of the Plotterkill stream gradient and geomorphological characteristics observed. Individual descriptions and a relative chronology are discussed in detail below.

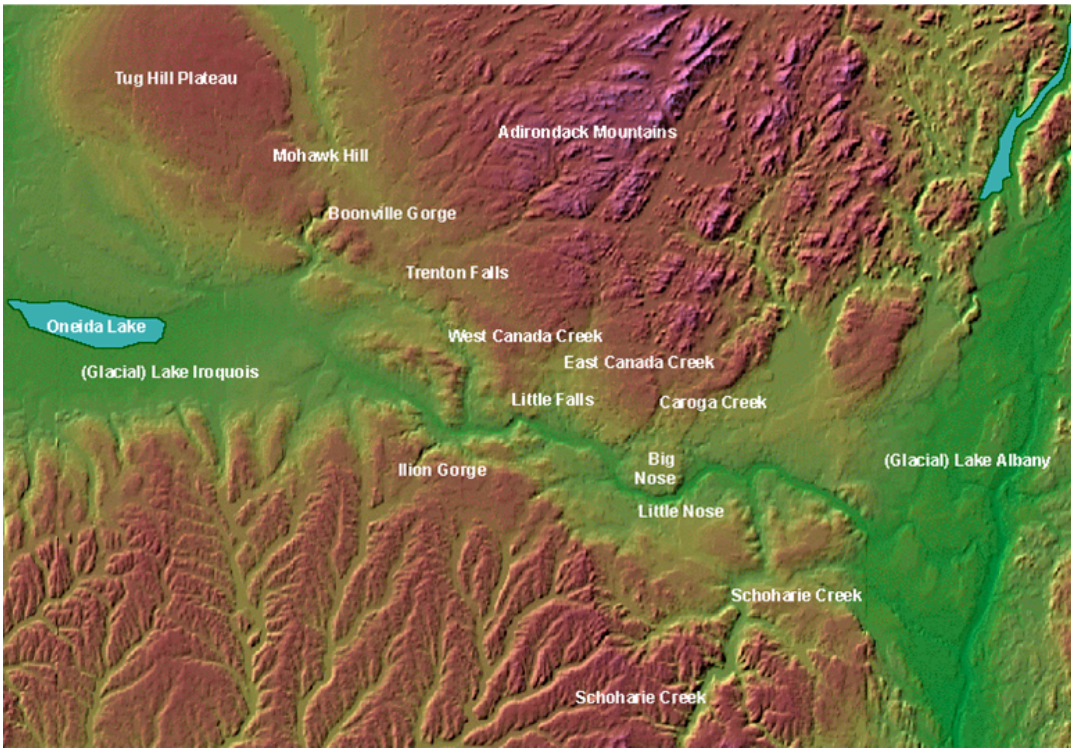

Figure 20. A Digital Elevation Model identifying where Glacial Lakes Iroquois and Albany would have existed during deglaciation. The Iromohawk Channel connects the two lakes (Paul Kessler, 2007, unpublished).

[A] Glacial Lake Iroquois

As the Laurentide Ice Sheet receded from its maximum extent along southern Long Island, New York, and northern New Jersey to southern Canada from ca. 21,000 to 13,000 years ago, many proglacial lakes formed in New York State as a terminal moraine dammed meltwater flow to the Northern Atlantic at the Narrows dam near New York City (Figure 21) (Donnelly et al., 2005). In the present-day Lake Ontario Basin of eastern New York, Glacial Lake Iroquois formed as the ice sheet receded and received overflow from the Great Lakes to the west (Teller, 1987).

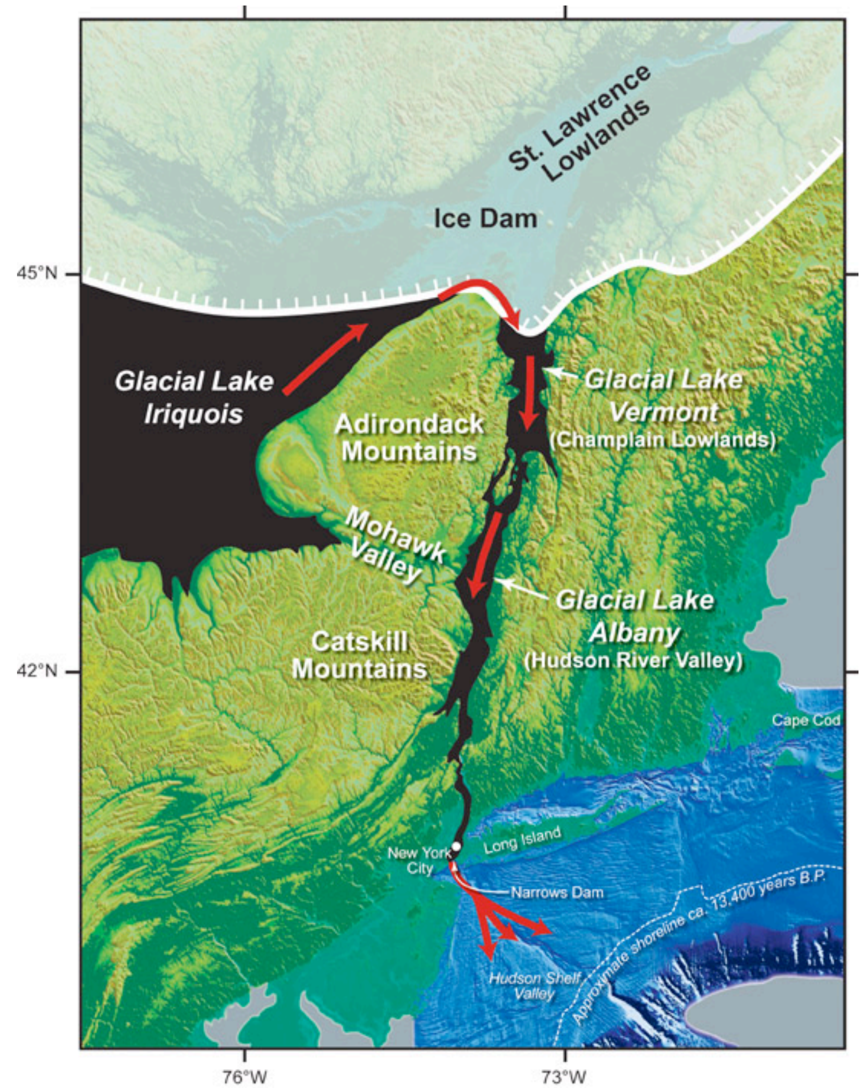

Figure 21. The Glacial lakes and drainage patterns in New York State as Laurentide Ice Sheet receded to the north approximately 13,400 cal yr B.P. (from Donnelly et al., 2005).

Various authors have presented an age range of Lake Iroquois based on radiocarbon dating of organics from Lake Iroquois sediments and Lake Frontenac sediments, which succeeded Lake Iroquois. Other events during deglaciation have influenced the estimated age of Lake Iroquois as well, including the recession of the ice sheet above the northwestern flank of the Adirondack Mountains and the initiation of the

Champlain Sea. Based on fossilized wood from Iroquois sediments, Muller and Prest (1985) provide an estimated ^{14}C age of the lake of to be 12,660 +/- 400 and 12,080 +/- 300, which overlaps between ~15,600 yr B.P. to 13,800 yr. B.P. (Donnelly et al., 2005). Muller and Calkin (1993) suggest the lake existed for "a few centuries" and came into existence between 14,950-14,300 and 14,030-13,825 cal yr B.P. (12,500 and 12,100 ^{14}C yr B.P). Muller and Prest (1985) note that Glacial Lake Iroquois drained when the outflow shifted to the north of the Adirondack Mountains. As the ice sheet receded north, the Covey Hill ice dam in northern Vermont and New York failed. At this point, Lake Iroquois drained catastrophically down the Hudson Valley and into Glacial Lake Vermont-Albany. Pair and Rodrigues (1993) provide a minimum age for deglaciation of the northwestern Adirondack flank and incursion by Lake Iroquois of 15,087-14,111 cal yr B.P. (12,500 +/- 140 ^{14}C yr B.P). By 14,270-14,050 cal yr B.P. (12,300 ^{14}C yr B.P.), the Laurentide margin had retreated enough to allow Lake Iroquois to spill through a lower outlet and into the Champlain Valley, which was still overflowing south to the Hudson Valley (Teller, 1987).

Two periods of significant drainage occurred in the Iromohawk channel. The first period was the eastward drainage of Lake Leverett from the Lake Erie Basin during the Erie Interstade, based on the Shed Brook Discontinuity and Little Falls Gravel in the western Mohawk Valley (Ridge, 1991). Lake Iroquois was the second Late Wisconsin water body to drain through the Mohawk Valley (Wall, 1995). Rome, New York is commonly referred to as the outlet for Lake Iroquois while the Covey Hill ice dam deterred meltwater from flowing to the north of the Adirondack Mountains (for example, see: Fairchild, 1932; Prest, 1970; Denny, 1974; Muller and Prest, 1985). Around 13,350 yr B.P., the ice sheet receded north of the Adirondack Mountains, allowing meltwaters from Lake Iroquois to drain into the Hudson Valley and Glacial Lake Vermont and Glacial Lake Iroquois (Donnelly et al., 2005). Based on this evidence, it is estimated that Lake Iroquois existed from ~15,600 yr B.P. to ~13,400 yr B.P. as the lake underwent catastrophic drainage and lake elevation levels lowered. Donnelly et al. (2005) suggests the lake underwent three major elevation drops since the Laurentide Ice Sheet receded north of the Adirondack Mountains, totaling ~120 meters with the largest drop of ~80 meters.

[B] Iromohawk Channel

The term "Iromohawk Channel" refers to the channel that stretches from Rome, New York, the point of Lake Iroquois outflow in the Mohawk Valley, to Glacial Lake Albany in the Hudson Valley, connecting the two lakes (Figure 20). Throughout deglaciation and Lake Iroquois drainage, the Iromohawk carried outflow until lake elevation levels dropped, changing base level and flow direction (north around the Adirondack Mountains). Wall (1995) indicates that many erosional and depositional features along the length of the Mohawk Valley can be attributed to Iromohawk drainage, ultimately shaping the landforms present today.

The Iromohawk Channel was active and full with both Glacial Lake Albany and Glacial Lake Iroquois were full. Lake Albany existed from ~16,300 yr B.P. to ~13,700 yr B.P. (Dineen and Miller, 2006) and Lake Iroquois existed from ~15,600 yr B.P. to 13,800 yr B.P (Donnelly et al, 2005), so the Iromohawk Channel was likely active for about

2300 years from ~16,000 yr B.P. to ~13,700 yr B.P. During these two millenia, meltwater flow deposited sediments throughout the channel, including the major phase of the deposition of the Scotia Gravels. Wall (2005) suggests these sediments were the main deposit of Iromohawk flow and exist at five locations surrounding the modern Mohawk River.

[C] Glacial Lake Albany

Glacial Lake Albany was the first lake to form in the Hudson Valley following deglaciation and successive lakes developed at lower levels as the glacial margin retreated northward and end moraines to the south were eroded (Teller, 1987). As the Late Wisconsin ice sheet receded northward through the Hudson-Champlain Lowland of eastern New York, a sequence of glacial lakes were formed. From 18,000 years ago to about 15,000 years ago, the glacier retreated from Long Island to the mid Hudson Valley. Around the vicinity of Newburgh, an ice or moraine dam developed and contained glacial meltwaters, filling the valley and surrounding areas and forming Glacial Lake Albany (Barnes, 2003). Lake Albany was believed to have stretched 160 miles from Newburgh, New York to Glens Falls, New York, lasting from 15,000 to 12,600 yr B.P. Continued glacial retreat caused isostatic rebound throughout the Capital District, and Lake Albany began to drain 12,000-13,000 cal years ago, forming a series of small lakes.

It should be noted that glacial lakes in the Hudson Valley underwent many phases and creating a descriptive chronology of the area is extremely complicated as lake levels continued to lower through time. The first lake determined was Lake Albany, which lowered and formed Lake Albany II. From this, Quaker Springs formed, followed by Coveville, Fort Ann I, Fort Ann II, and Fort Ann III (Wall, 1995). Wall (1995) presents a collective interpretation of Hudson Valley glacial lake level elevations in Table 1 below.

Table 1. Interpreted Hudson Valley glacial lake level elevations (modified from Wall, 1995).

	Location	
Hudson Valley Glacial Lake	Mechanicville/ East Line	Troy/ Schenectady
Albany I	350	340
Albany II	330	~310
Quaker Springs	300	~290
Coveville	240-220	~220
Fort Ann I	190	~180
Fort Ann II	150	~140
Fort Ann III	120	~110

While Lake Albany trended north to south throughout New York, depositing sediments throughout the capital district as drainage occurred, Lake Iroquois formed to the west in the Ontario.

Chronology

Creating a chronology for the formation and drainage of glacial lakes and meltwater channels in New York, especially in the Iromohawk system, is a difficult task as there is a lack of significant dateable materials. As previously discussed, various authors present different time ranges for deglacial events, but a general timeline can be constructed relating to glacial retreat and meltwater flow. The Laurentide Ice Sheet began its northern retreat about 21,000 yr B.P. ago (Donnelly et al., 2005). Connally and Cadwell (2003) suggest that the ice sheet withdrew up the Hudson Valley, north of the Mohawk Valley confluence, about 20,000 yr B.P. ago, releasing a flood of cold freshwater from the proglacial Great Lakes into this region and down the Hudson Valley. Following this retreat was the formation of Glacial Lake Albany, which existed from about ~16,300 yr B.P. to ~13,700 yr B.P. (Dineen and Miller, 2006) in the Hudson Valley, and Glacial Lake Iroquois in the Mohawk Valley, which existed from about ~15,600 yr B.P. to ~13,800 yr B.P. (Donnelly et al., 2005). It was during this time period that the Iromohawk Channel was active and full, depositing sediments throughout the channel. This is the major phase of deposition for the Scotia Gravels in the Mohawk Valley (~16,000 yr B.P. to ~13,700 yr B.P.). Around 13,350 yr B.P., ice retreat was sufficiently north of the Adirondack Mountains causing the Covey Hill ice dam to fail (Donnelly et al., 2005). This breach resulted in catastrophic flooding of the Hudson Valley as Lake Iroquois sent a pulse of meltwater to the north of the Adirondack Mountains and into Glacial Lake Vermont-Albany and out into the North Atlantic Ocean (Donnelly et al., 2005). This pulse of meltwater flooded Lake Albany, and the terminal moraine dam at the Narrows near New York City was breached and meltwaters drained into the North Atlantic, ultimately lowering the level of Lake Albany. This lowering of Lake Iroquois resulted in the abandonment of the Iromohawk Channel. At this point, one can envision that the Iromohawk Channel no longer served as a meltwater channel for the continental ice sheets, transitioning from a depositional environment to an erosional environment. From this point forward, it became the more limited Mohawk River.

Based on radiocarbon dating, Ballston Lake in the Ballston Channel formed around 12,900 +/- 70 cal yr B.P., which is evidence that the Ballston Channel was abandoned and the Mohawk River took a new route through the Rexford Knolls, creating the modern Mohawk River path (Toney et al., 2003). Incision of the Mohawk Channel then took place at Rexford knolls. In this scenario, 35 meters of downward incision took place since then. This estimate is based on the 340 foot elevation of the Scotia Gravels deposited by the active Iromohawk Channel down to the modern Mohawk River level of 224 feet. It is likely that a majority of this incision occurred during the first few thousand years.

The Effects of Deglaciation and Subsequent Drainage on the Plotterkill Creek

After creating a general overview of the Iromohawk System, Glacial Lake Iroquois, Glacial Lake Albany, and their subsequent drainage, the stream gradient and knickpoint evolution in the Plotterkill Nature Preserve can be analyzed in regards to deglaciation in the past 13,350 years. The formation of the waterfalls, or knickpoints, in the Plotterkill Nature Preserve were most likely a result of a base level drop of the Mohawk River in the past. Based on the general topography of the land and the underlying bedrock of the Schenectady Formation, it is estimated that the Upper Falls have eroded back approximately 700 meters to where they currently occur (Figure 22). In the scenario where the Mohawk River started incising downward around 12,900 cal yr. B.P. as Rexford capture occurred, headward erosion of the knickpoints has occurred at a long-term average of about 6 cm/year. This erosion was most likely not constant with time; a majority of the headward erosion probably would have occurred following a large base level drop and slowed through time as erosion proceeded with time.

Figure 22. Estimate of the headward retreat of the knickpoint in the Plotterkill Preserve that forms the Lower Falls on Rynex Creek (B1) and on the Plotterkill Creek (B2). The knickpoint is thought to have originated in the main steep topography at point A.

CONCLUSIONS

Based on a chronology of deglacial events and subsequent drainage in the Mohawk and Hudson Valleys of New York, the Plotterkill Creek lies in an area where the Iromohawk Channel carried meltwater directly into Glacial Lake Albany. Since the drainage of Lake Albany, the most significant erosion and downcutting of the Mohawk occurred in the area around Scotia, where the Iromohawk and Glacial Lake Albany met. This change is much less significant upriver and it is in fact zero at the drainage divide near Rome, New York. Therefore, the effects of base level change reflected in knickpoint formation and evolution is more significant in the Plotterkill than other upriver tributaries of the Mohawk River. Following the breach in the Covey Hill Ice Dam to the north of the Adirondack Mountains approximately 13,350 yr B.P., Glacial Lake Iroquois caused catastrophic flooding in the Hudson Valley, resulting in the failure of the moraine dam near New York City. This ultimately released glacial meltwaters into the North Atlantic Ocean and led to the progressive drainage of Lake Albany. As the lake elevation level of Lake Albany fell, the elevation of the Iromohawk River dropped as well, causing about 35 meters of incision in the Mohawk Valley in the Scotia Area. This base level drop is also believed to have resulted in the formation of the knickpoints, or waterfalls, observed in the Plotterkill Creek which, based on topography, have undergone approximately 700 meters of headward erosion since the abandonment of the Ballston Channel following the breach of the drainage divide at Rexford Knolls about 12,900 years ago, averaging approximately 6 cm/yr. From this point on, the modern Mohawk River began its course and has been incising into the underlying Schenectady Formation throughout this area.

Future work in the Plotterkill Nature Preserve and the greater Capital District is essential to better establish the role of deglacial events in the formation and evolution of geomorphological characteristics in tributaries of the Mohawk River. A better understanding of the terraces, land stability, historical land use, sediment transport, and knickpoint evolution in the area surrounding the Plotterkill Creek could further validate the role of Glacial Lake Iroquois, the Iromohawk River, the Iromohawk Channel, Glacial Lake Albany, and glacial meltwater drainage in the continuously changing Plotterkill Creek.

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APPENDIX A- OBSERVATIONS

Observations

J19- Plotterkill meets the Mohawk River
J15- Area is very flat, with a large amount of small cobbles
J13- To west, large cut bank with exposed soil, possibly glacial till
J11- Directly after train tunnel. Plunge pool in front, small terraces to east and west.
J9- Shooting through tunnel of train bridge.
J8- Portion between train tunnel and New York State Thruway tunnel.
J7- Shooting from train bridge to plunge pool in front of NYS Thruway tunnel.
J6- Small area where water running through the NYS Thruway tunnel and drops into a plunge pool.
J5- Shooting through the NYS Thruway tunnel.
J4- Small area where loose sediment ends and water drops into the Thruway tunnel.
J3- Looking at the NYS Thruway, shooting laser towards it. Small terrace to East.
J2- Stream meanders and splits. To the West is a large cut bank that exposes all soil, no bedrock. To the East is a small terrace. In the general area, there are some large cobbles along with loose sediment.
J1- Beginning of J data. Standing on sediment, there is a terrace to the East that continues downstream.
I37- Stream splits, with small bench consisting of larger cobbles (up to 0.5 meters). Small terrace to east. Mapped stream flowing on the west side as there is a large cut bank, approximately 3.5 meters that exposes glacial till.
I36- Channel is very wide, with a fill terrace to the west
I35- Tall fill terrace to west
I34- Many large boulders, small terrace to east
I33- Intersection of red and blue trails
I32- To the west is a sloped hill, and small terrace to the east opens
I30- Small sloped hill to east, terrace to west
I29- Many large and small cobbles present, possibly three terraces to east and west
I28- Base of small falls
I27- Measuring small falls, bedrock visible to east with a bedrock base
I25- Measuring small falls, bedrock visible to east
I24 through I18- Numerous small falls that form “steps”. Bedrock to east and west, as well as a bedrock base. Also present is a drainage gulley
I16- Bedrock exposed to west. Stream meanders and cuts into bedrock, with many large cobbles present
I15- Area with large amount of washout sediment with a large clast range. Thick exposure of bedrock to east
I14- Shooting in front of 1 to 2 meter plunge pool that contains boulders of bedrock. Bedrock exposed to east and west, along with bedrock base
I13 through I1- Many small falls that form “steps”. Stream meanders and wraps around exposed bedrock
I13- Small falls

I12- Small falls
I11- Small falls
I10- After small falls, stream meanders. Base consists of exposed bedrock, with a terrace to the west and bedrock to the east. Area is generally more sloped
I9- After small falls, approximately 0.3 meters. Terrace to east with a bedrock base
I8- After small falls, approximately 0.3 meters. Terrace continues to east with a bedrock base
I6- Terrace to west, bedrock to east. Many smaller cobbles in this area
I5- Plunge pool. Bedrock to east and west, as well as the base of stream
I4- Larger falls, shooting from shallow end of plunge pool
I1- Top of falls
E12- Shooting before small falls, approximately 0.9 meters
E11- Large bedrock exposure on both sides, along with a bedrock base. Few cobbles present
E10- Bedrock to east and west
E9- Bedrock visible to east and west. To west sediment and drunken trees visible on top
E8- Terrace to east. Area with steep gradient and small cobbles
E7- Continued terrace to east
E6- Massive bedrock wall to east, approximately 15-18 meters in height. Small bedrock wall to west, approximately 5 meters. This is an area of downcutting
E5- Large bedrock exposure to east and west
E4- Landslide to west, terrace to right. Many medium sized boulders are present
E3- Area with a large amount of cobbles and sediment, no bedrock exposed
E2- After plunge pool
E1- "Sergeant's Falls", bedrock base with a small, 'V' shaped waterfall
A1- Shooting upstream from "Sergeant's Falls"
A2-
A3- Area of loose sediment on some bedrock, some cobbles
A4- Thicker sediments, prominent terraces visible
A5- Stream splits with a bench in the middle. Continuation of terraces from A4
A6-
A7-
A8- Large terraces to east
A9- One good terrace to west, two good terraces to west
A10-
A11- Fill terrace to east
A12- Terrace to east continues from A11
A13-
A14- The red trail intersects the stream a few meters upstream
A15- Directly below two sets of utility lines
B1-
B2- Terraces to east and west
B3- Shooting in pipeline clearing
B4- Washout dam blocking the stream, with a deep pool under the dam. At the edge of the pipeline, the stream splits with water flowing to the east. Terrace to east with numerous possible flood water paths to east. Past the terrace on the east, there is a

steep hill. To the west is a terrace with a large man-made stone wall. Another terrace lies behind the stone wall. The bench present could possibly be a continuation of the terrace to the west

B5- Many small streams flowing into the Plotterkill from the east, which are possible flood water paths. Terrace to the west continues

B6-

B7- At least two terraces, possibly a third to the east. To the west is a shale wall with loose sediment and possibly a small landslide

Between B7 and B8- Dam from washout with deep pools formed. Bedrock is exposed, with imbricated rocks to the east.

B8- Large area of exposed bedrock, stream meanders. A pool, approximately one meter in depth, is present. Terrace to the east has continued

B9-

B10- Shale bedrock with overlying stream deposits. Possibly two terraces to the east.

C1- Shale wall to west, possibly two terraces to east

C2- Terrace to west, bedrock exposure ahead

C3- Stream splits, west side wide but dry, east side more narrow with running water. High terrace to east, low terrace to west

C4-

C5- Looking at washout, including trees and branches. High terrace to west

C6-

C7- Small landslide

C8-

C9-

C10- Tall bedrock exposure to east

C11-

C12-

C13- Large wall of bedrock to the east, bedrock base is exposed approaching C14

D1- Approximately 2 meter tall waterfall that is measured in two parts as a small break is present with large, deep plunge pool.

D2- Second portion of waterfall

D3- Where falls converge, moving to the east towards lower Plotterkill falls

D4- Base of lower Plotterkill falls

G1- Lower Plotterkill falls

H1- Top of lower Plotterkill falls. Many small waterfalls that form “steps”. All bedrock base

H2- Directly in front of small falls, small plunge pool. Bedrock exposed along with a bedrock base. Terrace to west and shale wall to east

H3- Top of small falls. All bedrock

H4- Terrace continued to west, not much bedrock visible. More cobbles and sediment present

H5- Many cobbles present. Bedrock exposed on top of slopes to east and west

H6- Shooting to the plunge pool of upper Plotterkill falls. Bedrock shale wall to west. Cobbles cover stream bed

H7- Upper Plotterkill falls

F1- Top of upper Plotterkill falls

F2- Bedrock exposed to west, possible terrace to east
F3- Continued terrace to east, no bedrock visible. Many large boulders and cobbles with imbricated rocks on floor
F4- Directly after bridge of red trail. At least one terrace to east, with many cobbles present
F5- Stream splits with a bench in the middle. Water flows from the west and begins to meander into fill terrace to west. Many cobbles present with a small terrace to east
F6-
F7- Stream still meandering and cutting into fill terrace
F8- Stream cutting into fill terrace to west
F9- Stream cutting into fill terrace to west
F10- Continued terrace to west. Area is very flat and long. There are still many cobbles present and no visible bedrock
F11-
F12- Long, windy dry stream bed cutting into fill terrace on east, possibly old stream flow. Bedrock base is exposed under stream
F13- Possibly two or three terraces to west. Many larger cobbles present
F14- Bedrock is exposed
F15- Terrace to west
F16- Bedrock to east, many large boulders
END OF PLOTTERKILL PRESERVE

APPENDIX B- FIELD MEASUREMENTS

Site	Waypoint	Latitude	Longitude	Observations	Distance up slope (m) – hypotenuse	Angle (degrees)	Angle (radians)	Rise (m)	Run (m)	Total Rise (m)	Total Run (m)
										0.0	0.0
J19				Mouth of Mohawk	58.5	1.9	0.03	1.9	58.5	1.9	58.5
J18					22.3	1.1	0.02	0.4	22.3	2.4	80.8
J17					15.4	1.4	0.02	0.4	15.4	2.7	96.2
J16					32.1	2.2	0.04	1.2	32.1	4.0	128.2
J15	209				40.8	1.2	0.02	0.9	40.8	4.8	169.0
J14					20	2.6	0.05	0.9	20.0	5.7	189.0
J13	208				52.5	1	0.02	0.9	52.5	6.7	241.5
J12	207				24.4	1.6	0.03	0.7	24.4	7.3	265.9
J11	206				68.6	1.9	0.03	2.3	68.6	9.6	334.5
J10				terraces, cobbles	9.4	1.2	0.02	0.2	9.4	9.8	343.8
J9				terraces, cobbles	59	1.9	0.03	2.0	59.0	11.8	402.8
J8	205	42 01.638	74 00.948	terraces, cobbles	32.3	1	0.02	0.6	32.3	12.3	435.1
J7				terraces, cobbles	64.8	1.8	0.03	2.0	64.8	14.4	499.9
J6				terraces, cobbles	1.8	32.1	0.56	1.0	1.5	15.3	501.4
J5				terraces, cobbles	123.5	1.9	0.03	4.1	123.4	19.4	624.8
J4				terraces, cobbles	4.1	8.6	0.15	0.6	4.1	20.0	628.9
J3	204	42 50.556	074 01.085	terraces, cobbles	35.8	1.2	0.02	0.7	35.8	20.8	664.7
J2	203	42 50.544	074 01.106	terraces, cobbles	42.8	1.6	0.03	1.2	42.8	22.0	707.5
J1				terraces, cobbles	74	1.5	0.03	1.9	74.0	23.9	781.4
I36	202	42 50.503	074 01.139	terraces, cobbles	52.5	2.1	0.04	1.9	52.5	25.8	833.9
I35	201	42 50.535	074 01.171	terraces, cobbles	71	1.1	0.02	1.4	71.0	27.2	904.9
I34	300	42 50.522	074 01.193	terraces, cobbles	36.3	2.3	0.04	1.5	36.3	28.7	941.2
I33				terraces, cobbles	25.8	2.1	0.04	0.9	25.8	29.6	966.9
I32	199	42 50.533	074 01.246	terraces, cobbles	79	2.4	0.04	3.3	78.9	32.9	1045.9
I31				terraces, cobbles	51	1.6	0.03	1.4	51.0	34.3	1096.9
I30	198	42 50.466	074 01.280	terraces, cobbles	7.9	12.2	0.21	1.7	7.7	36.0	1104.6
I29	197	42 50.466	074 01.295	terraces, cobbles	36	1.3	0.02	0.8	36.0	36.8	1140.6
I28	196	42 50.547	074 01.319	Falls, bedrock	45.2	1	0.02	0.8	45.2	37.6	1185.8
I27				Falls, bedrock	2.2	23.8	0.42	0.9	2.0	38.5	1187.8
I26				Falls, bedrock	10.7	0.3	0.01	0.1	10.7	38.5	1198.5
I25	195	42 50.471	074 01.341	Falls, bedrock	2.7	24.2	0.42	1.1	2.5	39.7	1200.9
I24				Falls, bedrock	15.8	0.2	0.00	0.1	15.8	39.7	1216.7
I23				Falls, bedrock	9.6	12.9	0.23	2.1	9.4	41.9	1226.1
I22				Falls, bedrock	8.4	5.1	0.09	0.7	8.4	42.6	1234.5
I21				Falls,	8.1	12.6	0.22	1.8	7.9	44.4	1242.4

				bedrock							
I20				Falls, bedrock	90.7	1.6	0.03	2.5	90.7	46.9	1333.0
I19	194	42 50.433	074 01.425	Falls, bedrock	1.9	6.8	0.12	0.2	1.9	47.1	1334.9
I18	193	42 50.449	074 01.433	Falls, bedrock	6	11.7	0.20	1.2	5.9	48.3	1340.8
I17					52.1	0.6	0.01	0.5	52.1	48.9	1392.9
I16				washout	50.4	0.8	0.01	0.7	50.4	49.6	1443.3
I15				washout	56.4	1	0.02	1.0	56.4	50.6	1499.7
I14	192	42 50.408	074 01.553	washout	58.4	1.3	0.02	1.3	58.4	51.9	1558.1
I13				Falls, bedrock	16.8	7	0.12	2.0	16.7	53.9	1574.7
I12				Falls, bedrock	15.4	2.6	0.05	0.7	15.4	54.6	1590.1
I11				Falls, bedrock	3.1	16.5	0.29	0.9	3.0	55.5	1593.1
I10	191	42 50.369	074 01.600	Falls, bedrock	55.6	1.3	0.02	1.3	55.6	56.8	1648.7
I9	190	42 50.352	074 01.630	Falls, bedrock	45.8	0.6	0.01	0.5	45.8	57.3	1694.5
I8				Falls, bedrock	33.5	1	0.02	0.6	33.5	57.9	1728.0
I7					22.6	0.9	0.02	0.4	22.6	58.2	1750.6
I6	189	42 50.323	074 01.656		58.7	1	0.02	1.0	58.7	59.2	1809.3
I5					54	0.8	0.01	0.8	54.0	60.0	1863.3
I4				falls	5.1	30	0.52	2.6	4.4	62.5	1867.7
I3	188	42 50.291	074 01.099		13.4	1.2	0.02	0.3	13.4	62.8	1881.1
I2					2	17.6	0.31	0.6	1.9	63.4	1883.0
I1				top of small falls	22	0	0.00	0.0	22.0	63.4	1905.0
E12	168	42 50.297	074 09.751	Small falls	5.3	20.5	0.36	1.9	5.0	65.3	1909.9
E11	167	42 50.285	074 09.750	bedrock	65.2	1.2	0.02	1.4	65.2	66.6	1975.1
E10	166	42 50.272	074 09.754	bedrock	34.5	1.3	0.02	0.8	34.5	67.4	2009.6
E9	165	42 50.284	074 09.817	bedrock	52.1	0.7	0.01	0.6	52.1	68.1	2061.7
E8	164	42 50.285	074 09.853	terrace, cobbles	39.8	2.7	0.05	1.9	39.8	69.9	2101.5
E7	163	42 50.275	074 09.840	terrace	20	1	0.02	0.3	20.0	70.3	2121.5
E6	162	42 50.217	074 09.817	bedrock	85	1.5	0.03	2.2	85.0	72.5	2206.4
E5	161	42 50.217	074 09.901	bedrock	74	1.1	0.02	1.4	74.0	73.9	2280.4
E4	160	42 50.210	074 09.930	landslide	52	2.2	0.04	2.0	52.0	75.9	2332.4
E3	159	42 50.205	074 09.956	cobbles	47.4	2.4	0.04	2.0	47.4	77.9	2379.7
E2	158	42 50.113	074 09.943		68.1	1	0.02	1.2	68.1	79.1	2447.8
E1	157	42 50.165	074 09.962	Sargeant's Falls	3.3	16.9	0.29	1.0	3.2	80.1	2451.0
A1	300Y	42 50.206	074 02.023	Sargesnt's Falls	23.3	0.8	0.01	0.3	23.3	80.4	2474.3
A2	301Y	42 50.152	074 01.970		23.1	0.5	0.01	0.2	23.1	80.6	2497.4
A3	302Y	42 50.151	074 01.978	terraces, cobbles	32.5	1.4	0.02	0.8	32.5	81.4	2529.9
A4	303Y	42 50.138	074 02.008	terraces, cobbles	23.2	0.6	0.01	0.2	23.2	81.6	2553.1
A5	304Y	42 50.144	074 02.027	terraces, cobbles	29.9	2.8	0.05	1.5	29.9	83.1	2582.9
A6	305Y	42 50.133	074 02.048		21.7	1.3	0.02	0.5	21.7	83.6	2604.6
A7		42 50.133	074 02.065		23.4	1.4	0.02	0.6	23.4	84.1	2628.0
A8	307Y	42 50.121	074 02.071	terrace	51.1	1.7	0.03	1.5	51.1	85.7	2679.1
A9	309Y	42 50.099	074 02.009	terrace	21.1	1	0.02	0.4	21.1	86.0	2700.2
A10	311Y	42 50.106	074 02.122		53	1.9	0.03	1.8	53.0	87.8	2753.2
A11	312Y	42 50.107	074 02.154	terrace	63.1	1.4	0.02	1.5	63.1	89.3	2816.3
A12	313Y	42 50.082	074 02.189	terrace	87.2	1.4	0.02	2.1	87.2	91.5	2903.4
A13	314Y	42 50.044	074 02.209		25.7	3.1	0.05	1.4	25.7	92.9	2929.1
A1	315Y	42 50.024	074 02.231		53.9	1.7	0.03	1.6	53.9	94.5	2983.0

4											
A15		42 50.020	074 02.250	Middle of power lines	28.3	0.4	0.01	0.2	28.3	94.6	3011.3
B1	126	42 50.01	074 02.274		51.1	1.9	0.03	1.7	51.1	96.3	3062.3
B2	127	42 49.98	074 02.261	terraces	35.9	2.6	0.05	1.6	35.9	98.0	3098.2
B3	128	42 49.959	074 02.293	Pipeline	29.6	1.7	0.03	0.9	29.6	98.8	3127.8
B4	129	42 49.962	074 02 304	washout, terraces	53.9	2	0.03	1.9	53.9	100.7	3181.7
B5	130	42 49.958	074 02.303	terraces, sediment	25	1.2	0.02	0.5	25.0	101.3	3206.6
B6					29	1.5	0.03	0.8	29.0	102.0	3235.6
B7	133	42 49.949	074 02.357	terraces	41.2	2	0.03	1.4	41.2	103.5	3276.8
B8	134	42 49.960	074 02.396	bedrock, terrace	35.7	2.2	0.04	1.4	35.7	104.8	3312.5
B9	135	42 49.960	074 02.411		28.3	1.9	0.03	0.9	28.3	105.8	3340.8
B10				Shale wall, terrace	61	1.4	0.02	1.5	61.0	107.2	3401.8
C1	143	42 49.950	074 02.480	Shale wall, terrace	28.5	2.1	0.04	1.0	28.5	108.3	3430.2
C2	144	42 49.937	074 02.485	terrace, bedrock	35.2	1.5	0.03	0.9	35.2	109.2	3465.4
C3	145	42 49.932	074 02.490	terraces	50.7	2	0.03	1.8	50.7	111.0	3516.1
C4	146	42 49.906	074 02.522		25.7	1.8	0.03	0.8	25.7	111.8	3541.8
C5	147	42 49.902	074 02.536	washout, terraces	46.3	2.9	0.05	2.3	46.2	114.1	3588.0
C6	148	42 49.869	074 02.547		11	0.6	0.01	0.1	11.0	114.3	3599.0
C7	149	42 49.868	074 02.549		36	1.7	0.03	1.1	36.0	115.3	3635.0
C8	150	42 49.846	074 02.565		95	2.1	0.04	3.5	94.9	118.8	3729.9
C9	151	42 49.858	074 02.650		42.4	0.9	0.02	0.7	42.4	119.5	3772.3
C10	152	42 49.860	074 02.669	bedrock	36.9	3.1	0.05	2.0	36.8	121.5	3809.2
C11	153	42 49.884	074 02.688		16.8	5	0.09	1.5	16.7	122.9	3825.9
C12	154	42 49.853	074 02.711		61.4	1.9	0.03	2.0	61.4	125.0	3887.3
C13	155	42 49.839	074 02.738	bedrock	77.6	1.9	0.03	2.6	77.6	127.5	3964.8
D1				falls	8.2	8	0.14	1.1	8.1	128.7	3973.0
D2				falls	2.2	26	0.45	1.0	2.0	129.6	3974.9
D3				falls	25.2	0.8	0.01	0.4	25.2	130.0	4000.1
D4	Base of PK falls			base of lower falls	17.3	5.5	0.10	1.7	17.2	131.6	4017.4
G1				lower FALLS	23.2	34.3	0.60	13.1	19.2	144.7	4036.5
H1				Top of lower falls	73	2.7	0.05	3.4	72.9	148.2	4109.4
H2	184	42 49.766	074 02.891	BR	8.7	8.2	0.14	1.2	8.6	149.4	4118.1
H3				sediment	24	1.3	0.02	0.5	24.0	149.9	4142.0
H4	185	42 49.738	074 02.904	sediment	60.7	1.9	0.03	2.0	60.7	152.0	4202.7
H5	186	42 49.753	074 02.946	sediment	114	1.9	0.03	3.8	113.9	155.7	4316.6
H6	187	42 49.732	074 03.017	sediment	54.7	2	0.03	1.9	54.7	157.6	4371.3
H7				upper FALLS	15.4	48.3	0.84	11.5	10.2	169.1	4381.6
F1	170	42 49.676	074 03.037	Top of upper falls	42.7	0.6	0.01	0.4	42.7	169.6	4424.3
F2	171	42 49.709	074 03.038	terraces, cobbles	80	1.8	0.03	2.5	80.0	172.1	4504.2
F3	172	42 49.672	074 03.100	terraces, cobbles	77	2.1	0.04	2.8	76.9	174.9	4581.2
F4	173	42 49.640	074 03.148	terraces, cobbles	58	2.3	0.04	2.3	58.0	177.3	4639.1
F5	174	42 49.637	074 03.188	terraces, cobbles	39.4	2	0.03	1.4	39.4	178.6	4678.5
F6	175	42 49.621	074 03.225	terraces, cobbles	28.1	1.8	0.03	0.9	28.1	179.5	4706.6
F7	176	42 49.623	074 03.218	terraces, cobbles	59.4	2.1	0.04	2.2	59.4	181.7	4765.9
F8	177	42 49.618	074 03.261	terraces, cobbles	42.9	1.4	0.02	1.0	42.9	182.7	4808.8

F9	178	42 49.580	074 03.264	terraces, cobbles	65.7	1.7	0.03	1.9	65.7	184.7	4874.5
F10		42 49.551	074 03.282	terraces, cobbles	73	1.6	0.03	2.0	73.0	186.7	4947.5
F11	179	42 49.520	074 03.316	terraces, cobbles	44.2	1.5	0.03	1.2	44.2	187.9	4991.7
F12	180	42 49.508	074 03.340	terraces, cobbles	65	1.9	0.03	2.2	65.0	190.0	5056.6
F13	181	42 49.449	074 03.396	terraces, cobbles	47.8	0.9	0.02	0.8	47.8	190.8	5104.4
F14				terraces, cobbles	37.1	2.2	0.04	1.4	37.1	192.2	5141.5
F15	182	42 49.475	074 03.432	terraces, cobbles	59.8	1.8	0.03	1.9	59.8	194.1	5201.3
F16				Off preserve	39.1	2.4	0.04	1.6	39.1	195.7	5240.3