

Sediments at Mill Dams in the French Creek, Chester County



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This project was funded in part by a grant from the Community Conservation Partnerships Program, under the administration of the Pennsylvania Department of Conservation and Natural Resources, Bureau of Recreation and the William Penn Foundation in support of the Schuylkill Highlands Mini Grant Program administered jointly by Natural Lands Trust and Schuylkill River Heritage Association.

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Executive Summary

A preliminary survey of legacy sediments at former mill sites along the main stem of the French Creek is carried out using historical documents, GIS, and site visits.

We find that at former mill sites where the mill dam’s location can be identified there are terraces of fine grained silty soils above the former dam. These terraces are consistent with literature descriptions of legacy sediment fill terraces under study in the nearby Conestoga River.

Mobilization of these sediments during high water events is evident from the condition of the banks and lack of vegetation. Establishing the extent and rate of sediment mobilization will be the next step in understanding the impacts these sediment may be having on the French Creek.

Legacy Sediments Survey

Introduction

The ground breaking research paper by professors Dorothy Merritts and Robert Walter titled “Natural Streams and the Legacy of Water-Powered Mills” challenged many of the assumptions made about stream form and floodplains. Their research shows that dams associated with water-powered mill sites trapped sediments over a period of centuries. We carry out a preliminary survey of potential legacy sediments on the mainstem of French Creek¹.

Prior to European settlement of southeastern Pennsylvania, sediments coming from the erosion of the primarily forested land was negligible, and the accumulation of sediments in stream valleys is estimated² at 0.003cm/yr. or approximately one inch per thousand years. The clearing of forests from about 1700 to 1850 accelerated erosion rates exponentially.

¹ The French Creek is composed of the Upper and Lower French Creek located primarily in northern Chester County in the southeast region of Pennsylvania.

² R. C. Walter, D. J. Merritts, *Science* 319, 299 (2008)

During the same time period, mill dams emerged as a prominent feature on the French Creek, collecting and storing the water to power grain mills, saw mills, paper mills, forges, and many other operations. The numerous mills also served as nuclei for new communities, as farmers, craftsmen, and merchants assembled around them to do business. There were at least 2,000 water-powered mills in Pennsylvania by the 1800s³. Eroded soil washed into the region's waterways, accumulating as sediments in the still water behind numerous mill ponds. Sediment accumulation would have occurred beginning in the early 1700s, and continues behind the dams which have survived through to our era.

Beginning in the mid-1800s, steam engines take over as the main source of motive power for mills, and most dams no longer received maintenance. As a consequence, many have failed, so that today the condition of former working mill complexes varies greatly from essentially intact to completely absent. Where the dams remain intact or moderately breached, the identification of legacy sediment deposits is straightforward. This report looks at two examples of mill dams in that condition, and uses these as GIS benchmarks. Where the dams have breached fully or disappeared entirely, the identification of potential legacy sediments requires a multi-step process which includes review of historical records, GIS desktop survey, habitat assessments and examination of the potential legacy sediment deposit.

While many of the mill dams on the French Creek can no longer be easily identified, these dams very likely left behind a legacy of sediments with much longer-lasting impacts to the French Creek. A better understanding of streambank and floodplain conditions within the French Creek watershed can better inform future restoration practices.

Legacy Sediments

Suspended and bedded sediment is the number one source of stream impairments recognized by the US EPA, making up 40% of all assessed impaired stream miles in the United States⁴. The mechanisms of impairments are well documented in the literature.

Legacy sediment deposits, where present, alter stream form and function in numerous ways. Often the streams are confined to channels running through the deposits, with exposed, vertical banks which erode easily and deliver nutrients and fine sediments into the water with each storm event. These deposits can range from one meter to over three meters deep, as documented in Lancaster County by Merritts and Walter.

The extent and impacts of legacy sediments have not previously been studied in the French Creek.

³ S. Walton, Geography, Landscape, and Mills. Pennsylvania State University, Medieval Technology & American History project (2014)

⁴ U.S. EPA. What Are Suspended and Bedded Sediments (SABS) Watershed Assessment of River Stability & Sediment Supply (WARSSS). (6 March 2012). Retrieved from <http://water.epa.gov/scitech/datait/tools/warsss/sabs.cfm>

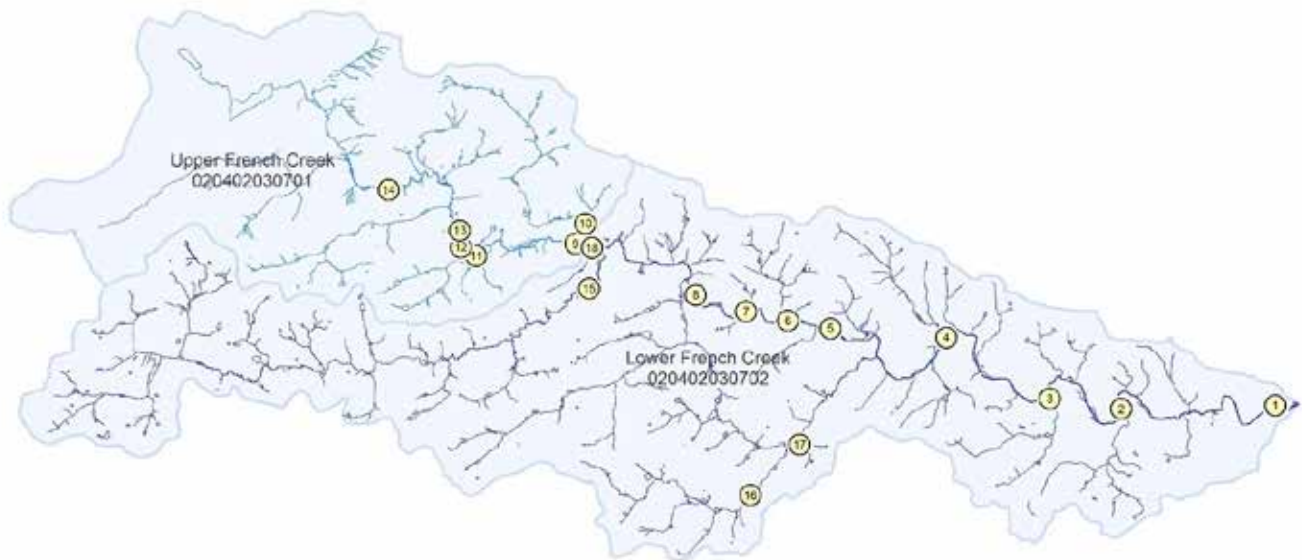
Survey Process

Desktop Survey

An initial desktop survey was carried out for 15 mill sites along the mainstem and an additional 3 sites on tributaries using a combination of historical maps, historical narratives, aerial imagery, topographical and soil surveys in GIS.

The 15 mill sites along the mainstem of the French Creek were the focus of this assessment. Two additional sites along the French Creek tributary Birch Run were used for GIS benchmarking; at these sites the mill dams are lightly breached and present both the original cause of the sediment build up (the dam) and exposed vertical banks of fine sediment; these are sites 16 and 17. Site 15 is along the South Branch of the French Creek in private ownership will be used as a long term study site.

French Creek Mainstem Historical Mill Sites



Historical Mill Sites Ownership and Location

Site	Stream Name	Atlas of Chester Co. (1873)	Latitude	Longitude	Purpose 1847 (Merritts)	Atlas of Chester Co. (1873)
1	French Creek Main Stem	Iron Works	40.1359	-75.5166	Canal	Canal and Mill Complex
2	French Creek Main Stem	Thos. Snyder	40.136	-75.5571	Oil, Grist	Spoke, Grist, Saw
3	French Creek Main Stem	Edwd. Millers	40.1384	-75.5757	Tilt Mill	Machine Shoppe, Saw
4	French Creek Main Stem	Anthy. Irey	40.1512	-75.6025	Grist, Saw	Grist, Saw
5	French Creek Main Stem	Jos. Sheeders	40.1536	-75.6328	Paper	Paper, Saw
6	French Creek Main Stem	Jn. W. Dixon	40.1554	-75.644	Oil	Paper, Saw
7	French Creek Main Stem	Abm. L. Detwilers	40.1574	-75.6549	Grist	Grist Mill
8	French Creek Main Stem	Buchers	40.161	-75.668		Bone Mill
9	French Creek Main Stem	Christmans	40.1719	-75.6993	Grist, Saw	Forge and Shade Factory
10	French Creek Main Stem	Priests	40.1759	-75.6966	Clover Mill	Grist, Saw
11	French Creek Main Stem		40.1699	-75.7255	Cotton Factory	
12	French Creek Main Stem	Knauer & Keims	40.1717	-75.7294		Grist
13	French Creek Main Stem	Knauers	40.1751	-75.7296	Grist, Saw	Grist
14	French Creek Main Stem	Knauers	40.1836	-75.748	Grist, Saw	Grist, Saw
15	French Creek South Branch	Davis	40.1628	-75.696		
16	French Creek Birch Run	Lewis Walleys	40.1204	-75.6549		Grist
17	French Creek Birch Run	B Nymans	40.1304	-75.6417		Grist, Saw
18	French Creek Main Stem Confluence	Coventry Forge	40.171	-75.695	Forge, Foundry	Missing

Geospatial PDFs

Geospatial PDFs were developed for 15 sites which allow the viewing of GIS layers in Acrobat Reader. The location of sites 8 and 11 could not be determined and a geospatial PDF was not developed for those sites. The layers in the PDFs include:

Leaf-off aerial imagery⁵. Imagery was useful in identifying existing structures and land uses.

SSURGO soils. The soils database shows the type of soils in the candidate legacy sediment terrace

Bare-earth hillshade. Imagery derived from 1 meter DEM was very useful in showing head races, dams, tailraces, and candidate legacy terraces. Imagery was used to delineate structures wherever possible.

Slope raster. The slope raster shows the degree slope across a given cell in the DEM. The DEM used was downsampled⁶ from the 1 meter DEM to a 10 meter cell size in order to show the slope over larger cells.

Aspect raster. The aspect identifies the downslope direction of the maximum rate of change in value from each cell to its neighbors. Aspect can be thought of as the slope direction. The values of the output raster will be the compass direction of the aspect.

Digital Elevation Model (DEM). Elevations were selected randomly across the fill terrace to assess overall flatness of the candidate terraces.

Habitat Assessments



Map of habitat assessment locations along Upper and Lower French Creek mainstems.

47 habitat assessments were carried out along the French Creek mainstem in early 2013 using the PA DEP⁷ format appropriate for riffle/run prevalence. The habitat assessment protocol

⁵ PaMap 2008

⁶ ArcGIS Aggregate tool

⁷ Form 3800-FM-BPNPSM0402

assesses the physical condition of the stream habitat. It is not a protocol for investigating legacy sediments; however, the assessment will identify bedloads of sediment, lack of riffle structure, eroding banks, and poor condition of bottom, which are all potentially signatures of legacy sediments which are either still in place or moving downstream.

Site Visits

Legacy sediment fill terraces where the dam is obsolete will typically consist of level deposits of fine grained material with the stream channel incised into the terrace. Exposed banks of sediment are near vertical and can show horizontal stratification from successive layers of sediment settling in the water behind the dam.

Legacy Sediment Survey Results

Summary

We found that the physical characteristics of the terraces behind former mill sites were remarkably consistent at Site 2 and upstream. Variations in elevations across the terraces were almost always less than 1 meter, and averaged less than half a meter. The upper layer of the terraces were consistently a dark fine-grained silty soil-like material. Horizontal stratification, which would occur in the still water behind dams, was visible at many sites. Beneath the sedimentary material was consistently a grayish, claylike layer. This feature was usually below the water level.

At Sites 15 and 18 distinct, horizontal layers of sediment enriched with charcoal were observed. The charcoal is very likely a fugitive from charcoal-making operations upstream, and can be used to date the sediments that they are found in.

Vertical banks, bare of vegetation, and 1 meter or more in height were the normal condition above the former mill dams. The trees and other vegetation on the surface of the terraces were observed hanging over the bank, indicating the ongoing removal of the terraces beneath them. This “stranded vegetation” presented trees in all stages of the process of being undercut and subsequently falling into the creek.

The condition of the epifaunal substrate above the mill dams was consistently poor; bottoms are mainly sand, silt and mud. Riffle/run structure is absent at most sites; a deep, wide channel of slow-moving water is typical.

Habitat assessments were carried out throughout the study area. Habitat assessments downstream or proximate to former mill sites identified poor cover, poor epifaunal substrate, and absence of riffles. Elsewhere along the mainstem, the substrate, riffle structure, and fish cover scores were consistently optimal.

Geospatial PDFs were developed from the data used in identifying the location and extent of terraces are provided in Appendix C. Habitat assessment results are provided in Appendix B.

Site 15: Davis South Branch Diversion

Located along the South Branch of the French Creek, site 15 features a stone dam built in 1797 to supply water to Coventry Forge⁸. The dam is breached. A race extended 1.2 km to the Coventry Forge tract to supplement the flow from the mainstem; this race is clearly visible on the DEM.

The GIS desktop survey for this site determined that soil types, slope, and aspect are consistent with a legacy sediment terrace (see Appendix B).

Exposed banks approximately one meter tall of fine grained material are present above the former dam. The bank is nearly vertical in many places, vegetated in others. Three distinct layers are visible above the water. At the base is a layer of grayish material with claylike properties, followed by a thin layer bearing charcoal, and the top layer is about one meter thickness of darker sediments. These layers extend around the terrace. The charcoal layer is consistently just above the grayish layer, and several cm thick in places. The first photo above shows this layer.



*Top: Layer of charcoal above grayish layer of claylike material in the streambank.
Bottom: Charcoal from the streambank layer with sediments washed off.*

Charcoal was produced for use at iron furnaces and forges at many locations in the French Creek, including Warwick Furnace and Reading Furnace located 3 km upstream from this site. Warwick Furnace began operation in 1737, and required 240 acres of hardwoods annually for

⁸ Historical account, published in the Dec 3, 1916 Reading Eagle newspaper

charcoal production. A 100 cc sample of the charcoal layer was collected and washed to recover the charcoal which is shown in second photo above.

The source of the charcoal in this layer very likely originates with the extensive charcoal production, transport, storage and use occurring upstream. This would date the sediment above the charcoal to the period after charcoal production began in the area, after about 1717. The bare, vertical banks suggest that bank material is falling into the stream.

Today, one of the banks at site 15 is showing many signs of erosion and collapse, while the other presents as stable rock and vegetation.

Site 18: Coventry Forge

The Coventryville mill site at the confluence of the mainstem and the south branch has a complex history of mills and forges construction, beginning with Coventry Forge (1717), the first iron forge in Chester County, the remains of which are now under the current Route 23. Several accounts also place a mill at the confluence of the French Creek



Stranded trees along streambank

mainstem and the South Branch. In reference to site 15 the Coventryville mill operations were large enough by 1797 to make diverting the South Branch to this mill dam viable. The site today is in Warwick County Park.

GIS survey and site visits show an extensive legacy sediment terrace extending approximately 200 meters upstream and 400 meters downstream from the point where the South Branch enters. Where the South Branch approaches the mainstem, it curves upstream and the flow of water where they join is opposed to the flow in the main stem.

Across much of this large terrace the elevation varies by less than one meter. Along the mainstem, near-vertical banks of one to two meters are exposed above the water. These banks are barren except for where the top vegetative cover has draped down. There are numerous

examples of large trees with root flares extending out over moving water. These stranded trees are typical of the identified terraces on French Creek.

Bank exposures are similar to those at site 15, with a grayish, claylike layer at the base, transitioning to layers of charcoal and brown sediments.



Eroding bank at Site 18 on mainstem showing grayish layer and charcoal



Horizontal layers at site 18



Eroding banks at site 18 on South Branch

Site 16: Walley's Grist Mill Site

The mill dam at site 16 is in good condition, with a minimal breach of approximately 40 centimeters. Sedimentation is ongoing from E&S failures upstream.

This site was used to calibrate parameters used in the GIS desktop survey. We looked at degree slope as well as aspect, and used those values in identifying potential terraces along the mainstem.



Mill pond at site 16

Site 17: Nyman's Grist and Saw Mills Site



View downstream towards dam.

Site 17 was also used to calibrate the GIS survey. The dam at site 17 is breached by approximately one meter, and the stream has begun the process of incising its way down into the sediment terrace. Bank failure is in evidence, with vegetation and trees stranded over moving water as the legacy sediment is washing away. The riparian buffer planting work is ongoing along the south side of the stream.

The entire site is in conservation ownership and represents a good opportunity to test alternative restoration strategies. The north bank at this site is currently not receiving any restoration work, and this is where alternative methods could be installed.

Site 14: Knauer's Grist and Saw Mill

This site is in private ownership and we were not able to access it. The GIS survey clearly shows via LIDAR the location of the former dam and head and tail mill races. A potential fill terrace extends for 0.3 km above the dam; elevation of the fill terrace varies by less than 1 meter across that entire area.

Site 13: Knauer's Grist Mill

The mill building for Site 13 is located on Route 23, and water arrived at the mill via a long head race which reaches almost to St. Peter's Village. The topography at the top of the head race made it difficult to determine if there is a fill terrace or if this is a normal wetland feature. Site visit is pending.

Site 12: Knauer and Keim's Grist Mill

This mill building is closely located to the mill building in Site 13 and very likely received its water from the same mill race.

Site 11: Winterbottom's Cotton Factory

We were unable to locate this mill site.

Site 10: Priest's Grist and Saw Mill on Rock Run

Rock Run has seen extensive exploitation for hydropower, beginning with the original Coventry Forge which was built on Rock Run in the early 1700s. The 1873 Atlas shows a dam which we have not been able to positively identify on LIDAR. A potential fill terrace is located above the likely dam site and features which are probably head and tail races are also visible. Additional historical research is needed to establish the chronology of mills at this site.

Site 9: Christman's Forge and Shade Factory

The 1873 Atlas shows the dam at site 9 located above the confluence of the South Branch and the Mainstem, and is probably a continuation of the mill activity described at Site 18. A large candidate terrace is located above the confluence. The mainstem is not deeply incised into the candidate terrace.



Site 9: Looking upstream from location of former dam.

Site 8: Bucher's Bone Mill

We were unable to locate features corresponding to the mill dam shown on the 1873 Atlas.

Site 7: Detwiler's Grist Mill

The dam at Site 7 is partially intact and the creek above it is not deeply incised into the candidate terrace. Vertical banks of fine-grained sediment with overhanging vegetation were observed. The substrate consists almost entirely of fine sands and mud.



Beginnings of incisement just above dam.

Site 6: Dixon's Oil Mill

The mill dam at Site 6 is partially intact. Currently the stream is about one meter below the level of the candidate terrace. The banks are near-vertical and un-vegetated, with characteristic stranded trees and vegetation. By most measures this site would be considered to have a high-quality riparian buffer, with mature trees and full canopy closure; yet the bank erosion is ongoing. Substrate at this site also consists almost entirely of fine sands and mud.



Stranded riparian buffer at Site 6

Site 5: Sheeder's Saw and Paper Mills

The mill dam at Site 5 is mostly breached. The bank between the candidate terrace and the stream is near-vertical and averaging two meters in height. Vegetation is mainly absent from the banks and large, stranded trees are evident. Substrate consists mainly of fine sands and mud.



Stranded vegetation at Site 5

Site 4: Irey's Grist and Saw Mills

The mill dam at this site could not be located. The head race is partially identifiable in LIDAR. The mill building and tail race are in good condition. The streambanks above the estimated location of the dam were investigated. These banks were between 0.5 and 2 meters in height. Sediment terraces, if formerly present, may have been mostly eroded away at Site 4.

The layers observed consisted of first, a grayish clay layer; second, a compressed layer of leaves and other organic material up to 2 cm thick; and a top layer consisting of darker, silty material. Vertical banks were exposed, un-vegetated, and stranded trees were common.



Leaf layer between underlying grayish clay and overlying darker, fine material.

Site 3: Rengeus' Tilt Mill

Site 3 is located above the Kennedy Covered bridge. The remains of the dam are visible below the surface of the water. The head race is in good condition. A large candidate terrace is located above the former dam site on the north side of the creek, and may also be present on the south side. Elevations across the terrace vary by less than 1 meter.



Site 3, the French Creek above Kennedy Bridge

Site 2: Rapp's Dam and Snyder's Mill Complex

Rapp's Dam was intact through the 1960's, when the mill pond was a destination for recreational activities. The dam was severely damaged by Hurricane Agnes in 1972. Recently, a pedestrian bridge has been built over the former dam and provides good access to the potential legacy sediment terrace on the other side.

Vertical banks of fine-grained material were consistently observable on both sides of the creek above the dam. Horizontal stratification of the bank soil layers was well-developed. Stranded trees and vegetation indicate that erosion is ongoing.

Estimating erosion rates for this site may be a straightforward process. Historic photos or older topographic maps could allow delineation of the creek as it was in the 1960s. The hurricane in 1972 marks the destruction of the dam and the beginning of stream incision through the sediments.



Pedestrian bridge and trail over Rapps Dam.



Terrace above Rapps Dam showing horizontal layers and stranded vegetation.

Site 1: Phoenix Iron Works Mill Complex

This site became progressively industrialized since the founding of an iron furnace in the 1730's. The levelling, construction, and demolition of factories has probably taken place over sediments, but the current brownfield condition makes it problematical to identify fill terraces.

The creek is currently running in a deep channel, and the banks are overlain with centuries' worth of industrial by-products: slag, bricks, iron scrap, etc.



View upstream within terrace, showing steep banks and industrial rubbish.

Restoration Prioritization



North bank of the Birch Run at Site 17

Bank erosion at legacy sediment sites on the French Creek main stem is very likely ongoing, extensive, and having a negative impact on water quality. Stabilizing and restoring these sites is clearly a priority for the French Creek. Four sites present themselves as good starting points.

Site 15 along the south branch of the French Creek is owned by a land conservation organization. At that site one side of the creek appears to have returned to a more natural state. The creek flows around the terrace with its outer circumference consisting of a rocky bank with no sediments in evidence (see geospatial PDF in appendix C). The inner bank consists of exposed sediments which are eroding away. A possible restoration strategy would be to remove the terrace adjacent to the stream and install rocks and vegetation similar to what is in place on the other bank.

Site 17 is owned by West Vincent Land Trust. Riparian buffer plantings are already in place on the south bank and are being carefully maintained by a volunteer group. Incisement of the stream into the terrace is in its early stages but could progress rapidly if further failure of the dam occurs. This suggests that any restoration strategy will need to include the fate of the mill

dam. The north bank of the stream presents an excellent opportunity to try out a combination of vegetation stabilization techniques and laying the bank back to a more natural contour.

Site 18 at the confluence of the south branch and the main stem of the French Creek exhibited tall banks of sediment which appear to be eroding rapidly. The banks of the creeks there as they appear in the 2008 LIDAR specifically do not agree well with the outlines in the NHD. The south branch currently turns northwest where it enters the main stem and its flow is opposed to the flow in the main stem. The south branch may be undergoing an adjustment at the confluence and this process would release large amounts of sediment. Restoration strategy at this site would be developed after a formal engineering assessment. It should be noted that this site is located within county-owned Warwick Park and that freshwater mussels are present above and below this site.

Site 16 on the Birch Run has a large sediment terrace behind a dam in very early stages of failure. The sediment terrace there is currently functioning as a wetland and supports a variety of wildlife. This site represents a good opportunity to carry out a cost benefit analysis on the merits of maintaining the dam in good condition versus the long term consequences of dam failure and sediment release.

Prioritization beyond these four sites will require estimates of the sediment being generated at each site.

Recommendations

1. Develop a comprehensive database for historical records pertaining to mill sites on the French Creek and continue the process of identifying former mill sites.
2. Employ carbon dating or other means to verify the age of the sediments just above the grayish clay-like layer at two or three sites.
3. Determine the best method(s) to measure the rate of bank erosion.
4. Carry out total phosphorous and total nitrogen analysis on the terrace materials.
5. Develop better information about the sediment bedloads currently in the creek.

Appendix A: GIS Desktop Survey Methods

An initial desktop survey was carried out for 14 mill sites along the mainstem and an additional 3 sites on tributaries using the following data sources:

- Image overlays of sections from the 1873 Atlas of Chester County were used to locate and delineate dams, head races, tail races, and mill buildings along the French Creek main stem
- High resolution Digital Elevation Models, DEMs, derived from PAMAP 2008 LIDAR⁹, were used to delineate dams, head races, tail races and terrace features above former and existing dams.
- The Soil Survey Geographic database, SSURGO, provided soils information for the candidate legacy sediment sites.
- National Hydrography Dataset
- Historical accounts

Appendix B: GIS Desktop Survey Results

GIS Layer	Legacy Sediment Terrace Indicator Use
Leaf-off aerial imagery	Agriculture use, where present nearby, does not extend onto candidate terraces. Drainage ditch is occasionally present between the candidate and ag field.
SSURGO soils	Silt Loam soil type across entire candidate
Bare-earth hillshade	Candidate terrace feature present upstream of dam, generally absent below dam.
Slope raster	Slope averages less than 2 degrees across entire candidate terrace
Aspect raster	Direction of slope across terrace agrees with direction of water flow

⁹ <http://www.dcnr.state.pa.us/topogeo/pamap/lidar/index.htm>

GIS Desktop Survey Results

Site	Leaf-off aerial imagery	SSURGO soils	Bare-earth hillshade	Slope raster	Aspect raster	Estimated Area
1	n/a, site is brownfield	Udorthents, shale and sandstone	Terrace-like feature with stream running through heavily-incised banks	Majority of terrace slope is 0.5 – 2.0 degrees; portions at 2.5 degrees	Terrace aspect agrees with stream flow	79,000 sq m
2	Forested, non-agriculture	Rowland silt loam; Croton silt loam	Terrace-like feature with steep, heavily-incised bank along stream	Terrace slope is 0.5 – 2.0 degrees	Terrace aspect agrees with stream flow	42,000 sq m
3	Forested; ag lands stop before candidate terrace feature, with drainage ditch present between feature and ag field	Rowland silt loam; Bowmansville-Knauers silt loam	Terrace-like feature; banks steeply sloped	Terrace slope is 0.5 – 2.0 degrees	Terrace aspect matches stream flow	30,000 sq m
4	Forested; cultivated ag fields stop at border of candidate terrace	Bowmansville-Knauers silt loam	Terrace-like feature with steep, incised streambank	Terrace slope is 0.5 – 2.0 degrees; slope increases sharply at streambank	Terrace aspect agrees with stream flow	15,000 sq m
5	Forested non-ag	Codorus silt loam; Gladstone-Parker gravelly loams; Gladstone gravelly loam	Terrace-like features with steep stream banks	Slope is 0.5 – 2.5 degrees	Terrace aspect agrees with stream flow	19,000 sq m
6	Forested non-ag	Gladstone gravelly loam	Terrace-like feature with steep streambanks	Center of the terrace has a slope less than 2.0 degrees; terrace periphery has slope between 2.5 and 5.0+ degrees	Terrace aspect agrees with stream flow	5,000 sq m
7	Forested non-ag; drainage ditch apparent on border of western candidate terrace	Western terrace Codorus silt loam; eastern terrace Gladstone gravelly loam	Terrace-like features bordering stream with incised banks	Majority of both terraces have slope of less than 2.0 degrees; small portions have slope of 2.5-5.0 degrees	Aspect of both terraces agree with stream flow	20,000 sq m
8						
9	Forested non-ag	Hatboro silt loam; Penn silt loam	Terrace-like feature	Terrace slope less than 2.5 degrees	Terrace aspect agrees with stream flow	25,000 sq m
10	Forested non-ag; cultivated fields stop before reaching candidate terrace	Bowmansville-Knauers silt loam	Terrace-like feature	Terrace slope less than 2.0 degrees	Terrace aspect agrees with stream flow	8,000 sq m
11						
12	Forested non-ag; historic mill race still apparent	Hatboro silt loam; Lehigh channery silt loam;	Not distinct behind dam's historical location	Slope less than 2.0 degrees	n/a	n/a

		Brecknock channery silt loam	as noted in maps; surrounding area appears terrace-like			
13	Forested non-ag	Brecknock channery silt loam	Not distinct behind dam's historical location as noted in maps	Area slope between 2.5 and 10 degrees	n/a	n/a
14	Forested non-ag, small portion kept as lawn; nearby tree farm fields stop at borders of candidate terrace	Hatboro silt loam; Gladstone gravelly loam; Croton silt loam	Terrace-like feature; French Creek widens behind location of historic dam	Terrace slope less than 2.5 degrees	Terrace aspect mostly agrees with stream flow	27,000 sq m
15	Forested non-ag	Hatboro silt loam	Terrace-like feature, with steeply-sloped streambanks	Majority of terrace has slope less than 2.5 degrees; portions have slope between 2.5 and 10 degrees	Terrace aspect agrees with stream flow	5,000 sq m
16	Forested non-ag; large pond behind existing dam visible	Hatboro silt loam, Water, Cokesbury silt loam	Terrace-like feature, surface blends into pond	Terrace slope less than 2.0 degrees	Terrace aspect agrees with stream flow	30,000 sq m
17	Field, non-ag; wetland-type vegetation visible as tussocks	Hatboro silt loam; Codorus silt loam	Terrace-like feature with stream running through heavily-incised banks	Terrace slope less than 2.0 degrees	Terrace aspect agrees with stream flow	11,000 sq m
18	Non-ag, forests and mown fields; wetland-type vegetation visible; mill race from upstream dam visible in northern terrace	Hatboro silt loam; Cokesbury silt loam; Gladstone-Parker gravelly loams; Rowland silt loam; Califon loam; Penn silt loam	Terrace-like feature with stream running through heavily-incised banks after the confluence	Slope of terraces less than 2.0 degrees; slope at streambanks 2.5-5.0 degrees, with some small areas exceeding 5.0 degrees	Aspect of terraces agree with stream flows around confluence area	151,000 sq m

Appendix C: Geospatial PDFs

Geospatial PDFs are available in electronic format; a DVD is included with this report.

Appendix D: Habitat Assessment Scores

Date	Site	Latitude	Longitude	1. Instream Cover (fish)	2. Epifaunal Substrate	3. Embeddedness	4. Velocity/D epth Regimes	5. Channel Alteration	6. Sediment Deposition	7. Frequency of Riffles	8. Channel Flow Status	9. Condition of Banks	10. Bank Vegetative Protection	11. Disruptive Pressure	12. Riparian Width	Total Score
2/21/2013	1	40.20779	-75.76124	17	14	13	16	20	11	18	13	12	18	20	20	192
2/21/2013	2	40.20449	-75.76958	18	18	15	18	18	8	17	17	7	16	14	14	185
2/21/2013	3	40.20286	-75.76729	12	8	13	18	20	9	10	16	8	20	20	20	174
2/21/2013	4	40.20217	-75.76888	13	6	10	16	20	5	6	15	6	17	18	20	152
2/20/2013	5	40.18808	-75.77388	19	20	16	20	18	13	20	18	16	19	19	18	216
2/20/2013	6	40.1876	-75.76796	13	12	14	16	17	10	14	19	15	17	18	15	180
2/13/2013	7	40.18432	-75.752	13	3	10	7	14	6	3	20	14	16	13	14	135
2/13/2013	8	40.17685	-75.7515	10	1	6	6	18	4	1	20	13	19	16	17	131
11/20/2012	9	40.1697	-75.7256	16	16	18	20	14	17	19	17	15	13	11	10	186
11/20/2012	10	40.1697	-75.7256	14	18	17	19	17	15	17	15	18	14	15	10	189
11/15/2012	11	40.1717	-75.7186	15	13	15	15	20	15	13	19	15	20	20	19	199
2/13/2013	12	40.17303	-75.70752	15	13	14	20	20	9	15	17	10	18	20	20	177
2/13/2013	13	40.17195	-75.70199	8	6	9	7	20	5	5	20	6	19	19	18	142
2/13/2013	14	40.17194	-75.69694	17	19	14	20	19	15	19	17	16	17	16	18	193
11/15/2012	15	40.1715	-75.6925	14	13	16	19	20	17	11	20	15	13	12	9	179
12/19/2012	16	40.1718	-75.6897	16	13	17	18	20	13	16	18	15	15	10	9	180
12/19/2012	17	40.1702	-75.6866	10	9	12	16	20	10	8	18	9	9	6	6	133
12/19/2012	18	40.1684	-75.686	12	13	14	14	20	15	13	15	12	13	15	11	167
2/12/2013	19	40.16643	-75.6692	11	6	13	12	20	6	6	18	5	15	13	9	134
2/12/2013	20	40.16379	-75.67023	19	15	17	18	14	15	12	20	15	15	11	8	179
2/12/2013	21	40.16344	-75.66973	16	16	18	15	19	18	18	20	14	7	7	5	173
2/12/2013	22	40.16016	-75.66716	11	4	11	6	20	7	4	20	10	12	18	16	139
1/10/2013	23	40.1579	-75.6514	16	18	17	16	15	16	13	18	14	11	9	11	174
1/10/2013	24	40.1551	-75.6481	14	18	15	18	14	13	17	18	12	10	9	9	167
1/10/2013	25	40.1553	-75.6445	8	3	10	5	20	6	2	20	9	15	16	17	131
12/5/2012	26	40.155	-75.6404	11	16	13	16	14	10	11	18	12	12	14	14	161
12/5/2012	27	40.1549	-75.6395	16	17	16	15	20	17	16	15	15	19	17	19	202
12/5/2012	28	40.1522	-75.6215	14	16	17	10	15	17	19	15	14	15	12	10	174
12/5/2012	29	40.1479	-75.6209	16	15	16	16	20	18	14	16	12	18	19	12	192
1/30/2013	30	40.147929	-75.620973	17	15	18	15	15	19	17	19	19	15	16	16	201
1/30/2013	31	40.147274	-75.620121	16	17	15	16	19	14	18	16	12	15	17	14	175
12/5/2012	32	40.1473	-75.6202	14	14	17	15	20	16	16	15	14	18	17	17	193
1/30/2013	33	40.151249	-75.602451	14	18	17	15	15	13	18	16	14	16	15	15	185
11/28/2012	34	40.1516	-75.6019	15	18	17	18	20	16	18	16	18	17	16	15	204
1/30/2013	35	40.151841	-75.601353	15	20	18	16	14	15	17	18	14	12	11	6	178
11/28/2012	36	40.1516	-75.6016	16	18	17	20	20	19	19	17	17	20	15	9	207
1/30/2013	37	40.152554	-75.599402	15	19	16	15	18	17	20	19	18	7	7	6	177
1/30/2013	38	40.149537	-75.595072	13	14	15	16	20	14	15	20	13	18	20	20	200
12/11/2012	39	40.1379	-75.5804	13	14	16	18	20	12	14	19	13	13	15	19	186
12/11/2012	40	40.1381	-75.5761	9	2	17	12	20	7	5	19	11	18	16	18	154
12/11/2012	41	40.1396	-75.5763	14	16	14	18	14	16	13	18	15	14	13	10	175
1/8/2013	42	40.141	-75.5676	14	9	16	15	18	15	13	17	15	14	13	10	169
1/8/2013	43	40.1382	-75.5663	13	17	14	16	19	16	15	18	16	15	10	12	181
1/8/2013	44	40.1352	-75.5645	13	17	17	15	20	14	12	19	10	9	8	5	159
1/8/2013	45	40.1396	-75.5564	12	19	18	17	14	17	15	13	14	11	15	14	179
1/8/2013	46	40.1382	-75.5529	14	14	15	15	17	18	17	17	15	13	12	9	176
1/8/2013	47	40.1362	-75.5503	17	12	13	17	20	12	14	16	9	17	14	15	176