Southeastern Montgomery County Trout Unlimited
Huntingdon Pike Dam Removal and Natural Channel Design Stream Restoration Project on the Pennypack Creek

Final Project Report

December 15, 2007

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1.0 PROJECT OVERVIEW

The Huntingdon Pike Dam Removal and Natural Channel Design Stream Restoration Project on the Pennypack Creek was sponsored by the Southeastern Montgomery County Trout Unlimited. Funding was provided by a Pennsylvania Department of Environmental Protection (PADEP) Growing Greener Grant and a grant from American Rivers. The Southeastern Montgomery County Trout Unlimited contracted with F. X. Browne, Inc. to provide environmental assessments, design engineering, hydraulic and hydrologic modeling, permitting, construction services and oversight, and project management. The project was completed in December 2007.

1.1 Project Site

The Pennypack Creek is a Category I, FY 99/2000 priority watershed. The stream is designated as a Warm Water Fishery, Trout Stocking Fishery, and Migratory Fish Stream. The stream is listed on the Pennsylvania 303(d) list of impaired waters due to urban and small residential stormwater flows, flow alterations, and water flow variability. The impacts of stormwater flows on the Pennypack Creek are exacerbated by numerous road crossings, bridge abutments, and six dams, which alter natural stream morphology and sediment transport. The dams have a particularly negative affect on the water quality of the stream by impeding downstream flow, increasing sedimentation, decreasing dissolved oxygen upstream of the dams, increasing water temperature, and promoting downstream erosion. Stream conditions downstream of dams are subject to increased erosive forces as flow and sediment transport regimes are disturbed by the damming of the creek. In addition to these impacts, the dams also present a barrier to fish migration and degrade in-stream aquatic habitat. The Huntingdon Pike Dam on the Pennypack Creek was owned by Korman Corporation and was located near Huntingdon Pike in Abington Township.

1.2 Project Selection and Sponsorship

Southeastern Montgomery County Trout Unlimited proposed to remove the Huntingdon Pike Dam in order to improve water quality, restore natural stream flows and sediment transport, improve safety to recreational users of the stream, and support efforts of the PA Fish and Boat Commission and goals of the Delaware Estuary Program to restore migratory fish habitats in the Delaware Estuary.

This project supports a greater effort to remove all of the dams from the Pennypack Creek making it one of the few free flowing streams in this urbanized section of Pennsylvania. Coordinated dam removals on the Pennypack Creek will provide scientists with a valuable assessment tool to monitor the effects of system-wide dam removal on improving stream conditions to meet state-mandated designated uses.

1.3 Environmental Need for Project

The Pennypack Creek, state water plan subbasin 03J, is a Category I, FY 99/2000 priority watershed. Land-use in the Pennypack Creek watershed is predominantly residential with large areas of commercial land-uses. As a result of urban and small residential run-off, flow alterations, water flow variability, and habitat alterations occur. The creek flows through the city of Philadelphia and eventually joins the Delaware River within the Delaware Estuary.

Despite heavy urban and suburban characteristics of the watershed, large sections of the stream corridor are relatively intact. This condition is largely due to the presence of Pennypack Park, a division of Fairmount Park Commission in Philadelphia, Lorimer County Park, and lands held by the Pennypack Ecological Restoration Trust. The *Baseline Watershed Assessment of the Pennypack Watershed* conducted by the Philadelphia Water Department (Philadelphia Water Department Office of Watersheds, 2002) indicated that physical habitat impairments were most likely responsible for lack of pollution-intolerant species of fish and macroinvertebrate taxa. The Philadelphia Water Department Office of Watersheds assessment supports the findings of the PA DEP's *Watershed Restoration Action Strategy for State Water Plan Subwatershed 03J*, which indicates that sediment deposition, erosion, and variability of storm flows, as well as physical obstructions in the creek, are the causes of biological impairment.

The Huntingdon Pike Dam on the Pennypack Creek was located immediately upstream of Lorimer County Park in Abington Township. Natural sediment transport in this section of stream was affected by the bridge crossing of State Route 232 (Huntingdon Pike) immediately upstream of the dam and an abandoned bridge immediately downstream of the dam. This dam contributed to upstream sedimentation of the creek and promoted erosive forces downstream of the dam. Pooling of water behind the dam increased water temperature in this trout stocked stream and served to concentrate nutrient-laden fine sediments that are often preferentially washed over the dam in heavy rainfalls. This complex of dam and bridges immediately upstream of the 230-acre, Lorimer Park passive recreation area had obvious detrimental effects on stream water quality and aquatic habitat in the Pennypack Creek within the park.

Removal of the Huntington Pike Dam promoted water quality by restoring natural stream sediment transport and allowing the stream to reconnect with its floodplain at the site and in the natural areas of Lorimer Park. Dam removal had beneficial effects on the temperature profile of the stream, as well as allowing for the restoration of unimpeded flow and pool, riffle, and run features, and a natural stream profile. Follow-up stream channel restoration activities reduced sediment loading to the stream from eroding banks, reconnected the stream to its floodplain, and created critical habitat for aquatic organisms.

This dam removal and restoration project is part of a greater effort to remove dams from the Pennypack Creek, restore a more natural flow regime, improve in-stream habitat and fish passage, and improve the feasibility of reintroducing breeding populations of native Hickory Shad to the Pennypack Creek. Watershed partners involved in this regional effort include the Fairmount Park Commission, Montgomery County Department of Parks and Recreation, PA Fish and Boat Commission, Pennypack Ecological Restoration Trust, and the Southeastern Montgomery County Trout Unlimited.

1.3 Connection with Watershed-Wide Flow Obstruction Removal Efforts

The Fairmount Park Commission and Philadelphia Water Department Office of Watersheds are working on the removal of two dams on the lower Pennypack Creek (Frankford Avenue and

Rhawn Street) and upgrading fish passage around an exposed sewer lateral within Pennypack Park. These efforts on the lower portion of the creek are the beginning efforts to reopen the creek to migratory fish passage and mitigate streambank erosion in the park caused in part by these dams.

Southeastern Montgomery County Trout Unlimited has also sought funding, through Fish America, to remove the Bethayres Dam in Lower Moreland Township. This dam is upstream of the Huntingdon Pike Dam and the removal of both of these dams will provide a natural connection between the protected lands of Pennypack and Lorimer Parks and Pennypack Ecological Restoration Trust lands in Lower Moreland Township. The removal of these dams will also allow for more natural sediment transport through the Pennypack Creek and provide an opportunity to reduce erosion and restore natural stream morphology throughout this reach of stream.

Montgomery County removed the Old Huntingdon Pike Bridge. This bridge was immediately downstream of the Huntingdon Pike Dam and was in a state of disrepair. The removal of the bridge and the Huntingdon Pike and Bethayres dams present an opportunity to improve stream hydrology for a 1.4-mile stretch of the Pennypack Creek. These projects provide a good opportunity to monitor the effects of dam removal and recovery of stream hydrology when a series of obstructions are removed in concert.

Once the dam and old bridge were removed, natural streambanks and in-stream channel morphology were restored. Southeastern Montgomery County Trout Unlimited has been implementing habitat improvement projects in Lorimer Park since 1999 and has continued these projects in the area after the dam removal. These efforts have reduced erosion and degradation of aquatic habitat in the Pennypack Creek as it flows into Lorimer Park.

1.4 Project Permitting

Southeastern Montgomery County Trout Unlimited received a restoration permit waiver under Section 105.12 in PADEP’s Chapter 105 Rules and Regulations for the removal of the dam and construction of natural stream channel morphology restoration practices. Southeastern Montgomery County Trout Unlimited’s consultant, F. X. Browne, Inc., provided Erosion and Sediment Control Plans and obtained NPDES permits.

1.5 Funding

The Huntington Pike dam removal project has reduced nonpoint source pollution and erosion in the Pennypack Creek watershed. The dam removal and subsequent natural stream design mitigation project has:

- reduced sediment loading to the stream due to downstream bank erosion,
- restored natural stream sediment transport,
- reduced stream flow variability experienced in Lorimer Park,
- reconnected the stream with its floodplain in the project area,

- improved safety for recreational users of the stream, including construction of an launch access ramp for non-motorized boats,
- promoted the restoration of migratory fish populations in the watershed, and
- improved in-stream aquatic habitat to assist the stream in attaining its designated uses.

This project significantly advanced the non-point source reduction goals of the PADEP's Growing Greener Program, as well as the goals of the *Management Plan for the Delaware Estuary* and Pennypack Creek River Conservation Plan (in progress). As a result, funding for this project was provided by a PADEP Growing Greener Grant for $50,000 and a grant from American Rivers for $50,000.

Huntington Pike Dam prior to removal

2.0 PROJECT DESIGN

This section of the report summarizes the design procedure for the demolition and removal of a rock and concrete dam and the abandoned and dilapidated Old Huntingdon Pike Bridge (OHPB) downstream of this dam by the Southeastern Montgomery County Trout Unlimited. A location map and photos of both the dam and bridge are included at the end of this design summary in Appendix A. This project also addressed the natural restoration design of the stream channel and stabilization of the stream banks following the removal of the above stream obstructions.

2.1 Project Natural Stream Channel Morphology Design

The proposed project area included approximately 300 linear feet of the Pennypack Creek, extending from the Rt. 232 PennDOT Bridge to an existing railroad bridge in Abington Township, Montgomery County, Pennsylvania. The dam was located approximately 100 ft. downstream of the Rt. 232 PennDOT Bridge.

The project consisted of removing the existing dam and redesigning the stream channel and floodplain geometry using natural channel stream design methods to more effectively handle the flow and sediment transport regime in Pennypack Creek after dam and bridge removal. This redesign of the stream channel included regrading streambank slopes to restore hydraulic connectivity with the adjacent floodplain.

2.2 Existing Conditions Characterization and Assessment of the Project Site

2.2.1 Field Assessment Summary

- Existing conditions were visually assessed by F. X. Browne, Inc. Restoration and construction options were also assessed. Photographs were obtained.

- Bank, channel, and floodplain topography, including existing structures such as the dam and Old Huntingdon Pike Bridge were surveyed in the field.

- A wetland delineation was performed. The survey and wetland data were incorporated into the project's Existing Features Plan.

- Pavement and sub-pavement sediment samples of streambed material were collected.

- Sediment samples were taken upstream of the dam for pollutant testing, including priority pollutant metals, total metals, organochlorine pesticides, polychlorinated biphenyls, and percent solids.

- Nearby habitat for an endangered mussel species was identified in the Pennsylvannia Natural Diversity Inventory. Therefore, a search for this species was conducted and none was found.

2.2.2 Data Processing Summary

- The existing features survey data was brought into AutoCAD and was used to create a "TIN" topographic surface.

- Pavement and sub-pavement samples were analyzed for particle size distributions. The pavement and sub-pavement particle size distributions were combined into a single mixed particle sized distribution as shown in Appendix B.

2.2.3 Hydraulic Analysis Summary

- Peak flow calculations for SCS Type II design storms from multiple sites in the Pennypack Creek watershed were obtained from studies performed by R. Nalbandian of Temple University, as shown in Appendix C. The project area is located in subwatershed 7C and peak flows for 10-, 50-, 100-, and 500-year, 24-hour rainfall event were used.

- Stream morphology was determined using Rosgen methods with some values calculated in WinXSPro. FHA HEC-15 was used to calculate bank and bend shear stresses. These results are shown in Appendix D.

- Bankfull stage for the stream channel design was determined using regional curve information as shown in Appendix E.

- Manning's n values were estimated according to standard methods. N values for the floodplains along the project area were estimated to be 0.1. Manning's n for the channel was estimated to range from 0.044 to 0.063. N values for the channel were determined using the base and sub-factor method of Cowan (1956), Limerinos (1970) and Jarrett (1984). N values for the banks were determined using Manning's n Value table in the HEC- RAS version 3.1.3 model. See detailed explanation of Manning's n in Appendix F.

- Six cross-sections of the existing and proposed stream channel were created in AutoCAD. The cross-sections were spaced at 50 foot intervals along the proposed thalweg and were used to design the bank stabilization treatments. Cross-sections at station 12+55 and 12+35 were used as XS1 and XS2 in WinXSPro for Uniform Flow Analysis. Cross-section locations are shown in Appendix G.

2.2.4 Summary of Existing Conditions

Existing Dam - The existing dam was approximately 150 ft in length and 6-7 feet in height. The downstream face of the dam consisted of large flat stacked stones. The dam breast was composed of stone and/or concrete slabs. The dam was in poor condition; most of the water flowed over the central portion of the dam, where the dam crest had collapsed to create a low point. The upstream face of the dam consisted of large rock (12-36 in. rock) on a 4:1 slope.

Impoundment – The impoundment extended from the dam upstream at least 600-800 feet. Water was slow moving. The bed of the impoundment was not visible from the surface. Banks were generally well vegetated although some minor scouring was visible.

Stream channel downstream of the dam – Significant scour pool formation was visible immediately downstream of the dam face. Extensive mid-channel, gravel bar deposition was observed beginning approximately 30 ft. downstream of the dam and extending in the downstream direction for approximately 150 ft. The bars consisted mainly of medium to coarse gravel, with lesser amounts of fine gravel, sand, and cobble. Most of the bar surface was non-vegetated, but herbaceous and shrub vegetation occurred on the tops of some bars. Two trees (approximately 12" in diameter) occurred on one of the downstream bars. Flow passed around the central bars and through the left-most arch of the OHPB. Flow through the arch was rapid and the bed took on a run and then riffle configuration. Downstream of the OHPB, flow along the left channel was directed back to the center of the channel by the fill slope associated with the railroad bridge. A pool occurred in this area, and there was significant bank erosion (banks nearly vertical and 7-9 feet tall). A significant, but lower amount of flow was directed around the central bars and through the right arch of the OHPB. Flow again was rapid and the bed forms were "riffle like". The left and right flow paths met upstream of the railroad bridge where flow was slightly deeper and "run-like". Channel width between the dam and railroad bridge was approximately 150 feet and more than double the regional curve predictions for the site. Existing bankfull indicators were non-existent or unreliable based on best professional judgment.

2.3 Summary of Initial Assessments

Preliminary indications from initial site assessments suggested that limited fine sediment had accumulated behind the dam. The upslope face was observed to consist mainly of imprecated rocks for at least 20 feet upstream of the dam. Conversations with the Montgomery County Conservation District confirmed that the dam could be removed "in the wet" without coffer dams or a "pump around." In order to avoid sediment mobilization, the dam was removed incrementally and dewatered slowly. A similar dam was removed in this fashion in fall 2005 on the Pennypack Creek.

2.3.1 Bridge Removal

The overall project approach was to demolish and remove the OHPB prior to the dam removal. The parking area on Old Huntingdon Pike Road served as the primary staging area. A rock construction entrance was placed on Old Huntingdon Pike Road at the upslope end of the parking area. Silt fencing was placed along the route from the parking area to the dam. Aggregate was placed along the access route to create an even grade. Very limited amounts of silt and other fine material washed downstream when the bridge was demolished. Coarse bridge and mid-channel bar material was used as <u>fill</u> in the run and pool areas on the left side of the channel. The remainder of the material was stockpiled for later use on stream restoration.

2.3.2 Dam Removal

The removal of the dam immediately followed the bridge removal. All of the dam material was used to fill in the scour holes immediately downstream of the dam. The top course of the center of the dam was removed to permit dewatering and to limit sediment mobilization. Subsequently, each lower course was removed until the impoundment was completely dewatered. Then the rest of the dam was removed. See the photos in Appendix A.

2.3.3 Channel Restoration

The restoration area occupied a region of stream between meander bends that tended to have a riffle-like bed form. Therefore, the reach was recreated as a riffle. The existing longitudinal profile indicated that a target slope of less than 1% should be achieved by removing the dam and regrading the channel. The shallow slope allowed the restored channel to maintain the proposed riffle bedform. From the site assessment, it was determined that the most appropriate location for the new channel was along the right portion of the existing channel. This alignment connected the alignment of the stream segments above and below the restoration reach. Stone was sized to resist movement during the 100-year event and was embedded to a calculated scour depth.

The floodplain was designed to slope from 1-3% to meet existing grade. Fill for the floodplain consisted of fill and coarse material from the site. The fill was overlain by a layer of enriched organic silt/loam (approximately 12-18”) and seeded and planted according to E and S specifications.

Based on plans received from PennDOT, the footings of the railroad bridge and Huntingdon Pike Bridge abutments and piers were sufficiently deep (16-18 feet below normal water surface elevation) not to warrant concern of any instability in the bed material resulting from the channel restoration work. Scour calculations for the 100-year flow event were done to support this conclusion.

The streambed was composed of material excavated from a minimum of thirty inches (30”) of the existing streambed and material from the removal of the islands, thoroughly mixed and placed in the proposed channel to meet the final grade. Fill composed of bridge and dam spoils was used to underlie the streambed coarse gravel fill in areas where the quantity of streambed coarse gravel fill was insufficient to meet final grade.

2.3.4 Bank treatments

Determination of bank treatments was made based on average velocity and shear stress analysis for the bankfull and 100-year flow events. The bank stabilization consisted of a seed mix and appropriate riparian plantings secured by a minimum 4 feet deep R-4 rip-rap toe. Selective small tree and shrub container plants will be planted adjacent to the rip-rap toe by Trout Unlimited.

2.4 Natural Stream Channel Geomorphology Design

- Regional curves developed by various sources were used to estimate bankfull channel dimensions. Average values of bankfull channel dimensions from these regional curves were used for the proposed channel design as shown in Appendix E. The bankfull discharge (Q_{bkf}) was calculated to be 1143.7 cfs, bankfull width (w_{bkf}) was 68.99 feet, maximum bankfull depth (d_{mbkf}) was 3.38 feet and bankfull cross-sectional area (A_{bkf}) was 230.95 square feet.

- The target channel type for the restoration reach was determined to be “C” as defined by Rosgen, 1995, based on a review of the valley type and existing channel conditions.

- Design sinuosity was determined to be >1.2 for this reach of Pennypack Creek based on sinuosity ranges for C channels, as defined by Rosgen, 1995. A summary of the reach’s geomorphology is included in Appendix D.

- Reviewing the overall slope of the longitudinal profile, the minimum slope attainable was set as the target slope for the design of the restoration reach. This target slope was set at 0.0051 ft/ft.

- The proposed channel cross section was designed using regional curve data and bankfull geometry measurements from the stable reach downstream of the project area. Bed slope targets of 10(H):1(V) were established based on previous projects. The bank slopes for the restoration area were set at a maximum slope of 3(H):1(V).

- A surface was generated using points from the proposed channel geometry and contours were created. Proposed contours were tied into the existing conditions contours to produce a graded floodplain.

- Pavement and subpavement sediment streambed samples were collected and sieved as shown in Appendix B. Ratios between pavement and subpavement sizes were calculated, yielding high values outside of the range for use with entrainment analysis. The high ratios can be caused by a sediment supply that has been completely shut off resulting in an immobile, coarse lag deposit forming. An alternative method to calculate critical shear stress used the Shields curve. Since the proposed streambed will be a mixture of both sediment pavement and subpavement particle sizes, a composite particle size distribution was created using the particle size distributions of the existing material shown in Appendix B. A new composite D_{84} of 69.8 mm was then used with Shields Curve to determine a critical shear stress of 1.3 pounds per square inch as shown in Appendix H.

2.5 Bank Stabilization and In-Stream Structural Design

2.5.1 Streambank Stabilization Method

As shown in Appendix D, stream velocity at bankfull discharge within the restoration area was calculated by WinXSpro to be 5.92 ft/s. Bankfull stream shear stresses were calculated to be 0.80 lbs/square ft. Therefore, the hydraulic conditions present within the Restoration Area suggested that a pure bioengineering approach would be inadequate to protect the streambanks and channel from further degradation. The proposed banks were stabilized with a rip-rap toe trench except along the inside of point bars. The rip-rap for the toe trench was sized using the Ishbash method as outlined in the NRCS Engineering Field Manual Chapter 16 and the FHWA method (HEC 11). A safety factor of 2 was used to ensure that the riprap size would be stable. These methods are detailed in Appendix I. The invert of the riprap toe trench was placed at an elevation equal to or lower than the maximum scour depth elevation. Scour depth was calculated using the Modified Larson's Equation from the USACE's Ecosystem Management and Restoration Research Program publication ERDC TN-EMRRP-SR-05. See Appendix J for calculations.

2.5.2 Grade Control Structures

It was determined using the streambed sediment size distribution and the bed scour calculations for the restored channel that grade controls were not needed. Subsequent to dam removal and channel reconstruction, bedrock controls appeared in the streambed, thereby validating this decision.

3.0 F. X. BROWNE, INC.'S PROJECT RESPONIBILITIES

Deborah Slawson, Ph.D., an experienced fluvial geomorphologist and natural stream restoration designer, was the project manager for the Huntingdon Pike Dam Removal and Natural Channel Design Stream Restoration Project on the Pennypack Creek.

3.1 Scope of Work

Our detailed scope of work for this project included eight major tasks, which are described in detail below.

Task 1- Site Assessment and Survey

F. X. Browne, Inc. performed a visual survey of the dam, its reservoir, and the stream channel upstream and downstream of the impoundment to identify safe and proper engineering approaches to removing the dam, as well as infrastructure that needed to be protected or monitored during the dam removal.

F. X. Browne, Inc. assessed site characteristics critical for designing streambank stabilization measures and developing an effective dam removal construction plan. Our assessment included the identification of potential site access routes and staging areas that minimized impacts to regulated wetlands and other sensitive streamside habitats; evaluation of erosion and sediment control concerns; and assessment of streambank soil texture, soil moisture, light availability, and other site characteristics influencing the selection and design of streambank stabilization measures

Huntington Pike Dam Prior to Removal

F. X. Browne, Inc. reviewed available documentation relating to the location and structure of municipal and private infrastructure that was affected by the dam removal. This included water pipes, surface drains, irrigation systems, hydrants, septic and wastewater systems, roads, and bridge piers and abutments. In addition, we reviewed existing documentation to determine the current and past industrial uses of the river upstream of the dam and thus the likelihood that there were contaminants in the impoundment sediments.

F. X. Browne, Inc. performed a bathymetric survey to determine the amount of sediment collected in the impoundment. We also collected one composite sediment sample for laboratory analysis of grain size and bulk sediment chemistry to determine sediment characteristics including Target Analyte List (TAL) metals; and Target Compound List (TCL) volatile organics, pesticides, and PCBs. We used the results of this sediment analysis to determine the best approach for removing accumulated sediment from the impoundment and to determine sediment disposal requirements.

F. X. Browne, Inc. surveyed the stream channel both upstream and downstream of the dam to determine channel dimension, profile, and planform variables for use as a basis in designing channel restoration measures. All field survey procedures conformed to the "Guidelines for Natural Stream Channel Design for Pennsylvania Waterways" (Keystone Stream Team, 2002) and "Field Survey Procedures for Characterization of River Morphology" (D. Rosgen, 1996).

Task 2-Design of Dam Removal and Channel Restoration

F. X. Browne, Inc. developed a dam removal plan that detailed dam removal procedures and associated erosion and sediment control measures; addressed the removal and disposal of accumulated sediment within the impoundment; and proposed measures for protection of nearby structures. The site survey and assessment data collected under Task 1 was used to guide the dam removal planning process.

F. X. Browne, Inc. prepared design engineering plans for the dam removal and channel restoration for construction and permitting purposes. The design engineering plans presented planform, profile, and cross-sectional views of existing and proposed conditions for all sections of the restoration reach. The plans also provided construction details for in-stream grading, bank stabilization measures, and erosion and sediment control measures. The final plans included a landscaping plan, which specified type and location of all proposed plantings, as well as planting and seeding schedules for all restoration treatment areas.

F. X. Browne, Inc. submitted copies of the final plans to Southeastern Montgomery County Trout Unlimited and other project partners for review and comment, and revised the final plans based on review comments. The engineering plans and drawings are provided in Appendix K.

Task 3-Permitting

Pennsylvania's Dam Safety and Waterway Management permit requirements are normally waived so long as the removal of the dam does not imperil life or property or have an adverse impact on the environment and if plans are provided for restoration and stabilization of the project area. However, an Environmental Assessment was required in order to obtain the permit waiver. F. X. Browne, Inc. therefore prepared an Environmental Assessment for approval by PADEP, in accordance with 25 Pa. Code Chapter 105.12 (a) (11).

F. X. Browne, Inc. prepared an Erosion and Sediment Control Plan for the entire restoration area which showed the type and location of all proposed erosion and sediment control practices, construction access routes, staging areas, and limits of disturbance, as well as a detailed construction sequence and erosion and sediment control notes. This Erosion and Sediment Control Plan was submitted to Montgomery County Conservation District for approval, along with an NPDES Individual Permit for Stormwater Discharges Associated with Construction Activities for disturbance areas greater than one acre.

Task 4-Preparation of Bid Documents and Construction Specifications

F. X. Browne, Inc. assisted Southeastern Montgomery County Trout Unlimited with the preparation of bid documents and construction specifications necessary for implementation of the project. We provided Southeastern Montgomery County Trout Unlimited with the following bidding services:

- assistance with conducting a prebid meeting,
- review of bid submissions,
- recommendations for a bid award based on cost and technical merit of submissions,
- construction contract preparation, and
- bid award announcements.

The contract for construction and restoration activities was signed between Southeastern Montgomery County Trout Unlimited and the selected contractor.

Task 5-Construction

Huntington Pike Dam Removal Construction

Following contractor selection, the dam removal and channel restoration work was performed. Work was performed in accordance with the PADEP permit waiver conditions and the approved Soil Erosion and Sediment Control Plan. All necessary erosion and sediment controls were in place prior to any earth disturbance.

Accumulated sediment within the impoundment was managed prior to and during dam removal. The dam structure was removed using heavy excavation equipment. The dam was removed from the center of the proposed channel one course at a time to slowly dewater the impoundment in order to minimize sediment mobilization. Nearby structures, such as the upstream and downstream bridges, were protected and/or monitored as necessary during the dam removal. Where possible, salvageable materials, such as granite blocks, rock, and gravel were recovered for reuse.

Although past dam removals have shown that the exposed mud flats quickly and naturally regenerate with vegetation, stream channel restoration and habitat enhancement measures were implemented. The stream banks were regraded to a more natural gradient, disturbed areas were planted with native plants, and stabilization measures were implemented.

Special care was taken to ensure that newly exposed mudflats were not colonized by non-native invasive or noxious weeds. Southeastern Montgomery County Trout Unlimited conducted periodic site visits following installation to check for invasive species.

Task 6-Construction Observation

F. X. Browne, Inc. provided construction observation during the dam removal and channel restoration work to ensure that the work was performed in accordance with the design specifications and plans. The oversight also verified that unacceptable amounts of sediment were not released downstream and ensured that existing structures were protected during construction.

Huntington Pike Dam During Removal

As part of the construction observation we:

- held a pre-construction meeting,
- conducted weekly site visits through the duration of the project,
- reviewed pertinent documents and progress reports,
- coordinated scheduling and implementation of construction and restoration tasks, and
- conducted a final site evaluation.

Task 7-Pre- and Post-Construction Stream Monitoring

Monitoring how the river recovers after a dam is removed can provide extremely valuable information about rivers and river restoration. Data about sediment transport, plant recruitment and regeneration, riparian wetland response, aquatic and aquatic-dependent species diversity and strength, and water chemistry are all essential to assess the effects of the dam removal. The Philadelphia Water Department Office of Watersheds has been monitoring water quality and aquatic organisms and habitats as part of their five year biomonitoring cycle since 2002. One of these monitoring stations is located within Lorimer Park downstream of the proposed dam removal. This monitoring station will provide indications of the effects of the dam removal on the stream system.

Southeastern Montgomery County Trout Unlimited will monitor stream conditions within the project reach area both prior to and following dam removal. The monitoring effort includes measurements of dissolved oxygen, temperature, macroinvertebrate surveys, and stream channel profiles, as well as sample collection, to analyze sediment particle size distribution. The monitoring includes at least two pre-project and two post-project monitoring events to capture the effects of the dam removal on the stream system. F. X. Browne, Inc. will assist Southeastern Montgomery County Trout Unlimited with two of these monitoring events.

The results will be analyzed to document the water quality improvements expected from the dam removal and will be compared to the pre-project data.

Task 8-Project Management and Grant Administration

F. X. Browne, Inc. provided project management and grant administration services throughout the project. We provided grant progress reports to PADEP.

3.2 Partnerships

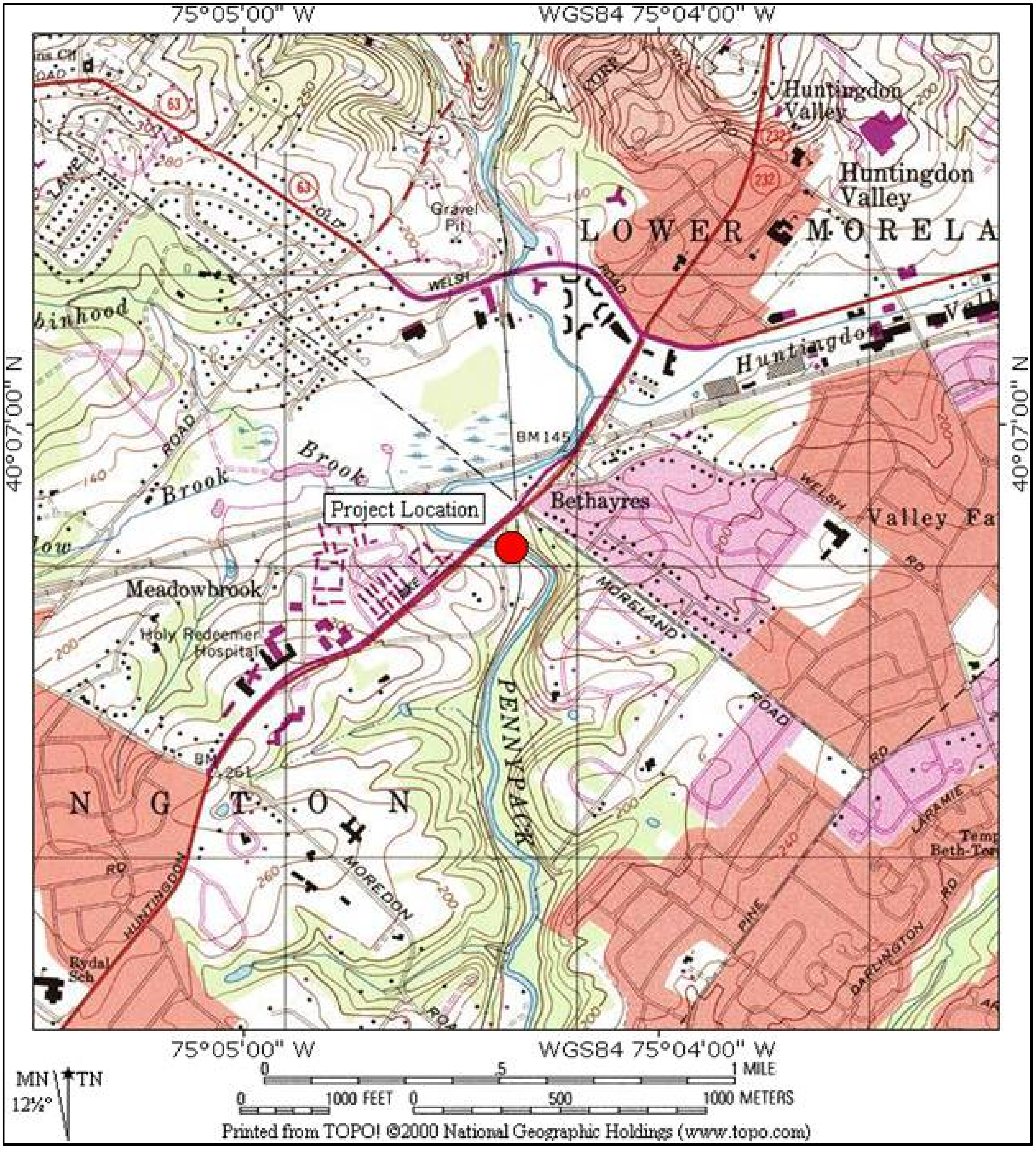
This project brought together a diverse group of project partners and participants including Southeastern Montgomery County Trout Unlimited, PA Fish and Boat Commission, F. X. Browne, Inc., the Pennypack Ecological Restoration Trust, and the Philadelphia Water Department Office of Watersheds.

F.X. Browne, Inc. coordinated the activities of the many partners in this project and provided engineering and consulting services to Southeastern Montgomery County Trout Unlimited.

Huntington Pike Dam Before Removal

Huntington Pike Dam After Removal

Appendix A
Project Location Map and Photos



Project Location Map
Huntington Pike Dam Removal

Before Dam Removal

Huntingdon Pike Dam crest, September 2007

Plunge pool below slumped dam crest, September 2007

Before Dam and Bridge Removal

Old Huntingdon Pike Bridge below dam, September 2007

PennDOT Huntingdon Pike Bridge, September 2007

During Dam Removal

Removal of center dam course for impoundment dewatering
and sediment control, December 2007

Partially dewatered impoundment, December 2007

Post Dam Removal and Stream Channel Restoration

Bedrock riffle in dewatered impoundment under the
PennDOT Huntingdon Pike Bridge, March, 2008

Site of former dam at non-motorized boat launch, March 2008

Former dam site with restored streambanks, March 2008

New channel in the former dam impoundment, March 2008

Appendix B
Particle Size Distribution

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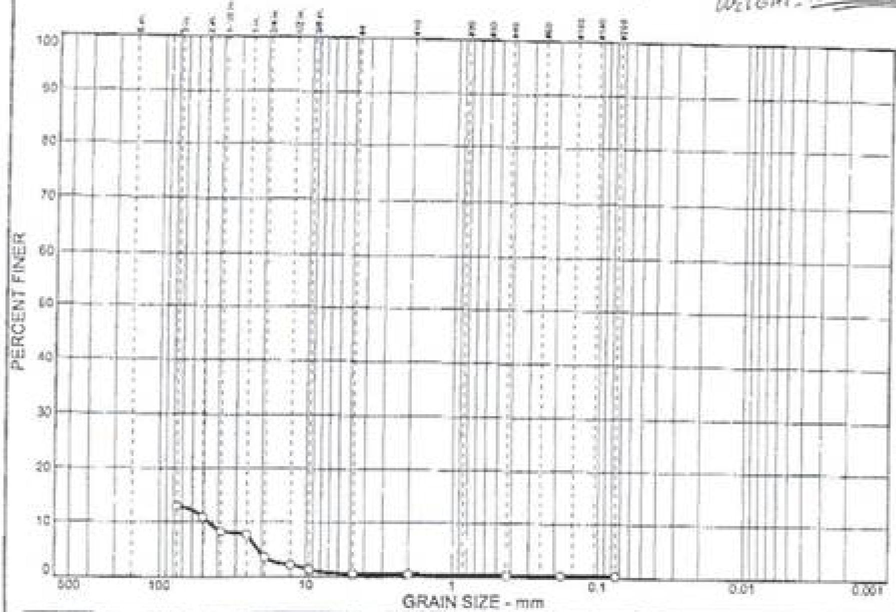
Particle Size Distribution Report

TOTAL SAMPLE WEIGHT: 1588.7 g



% COBBLES	% GRAVEL	% SAND	% SILT	% CLAY
87.1	12.3	0.2	0.4	

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
3 in.	12.9		
2 in.	10.9		
1-1/2 in.	8.2		
1 in.	7.7		
3/4 in.	3.6		
1/2 in.	2.2		
3/8 in.	1.3		
#4	0.6		
#10	0.5		
#40	0.4		
#80	0.4		
#200	0.4		

* (no specification provided)

Soil Description

Atterberg Limits

PL= LL= PI=

Coefficients

D_{85}= 78.9 D_{60}= D_{50}= 76.5
D_{30}= D_{15}= D_{10}= 46.6
C_u= C_c=

Classification

USCS= AASHTO=

Remarks

Sample No.: 1332 Source of Sample: point bar us of railroad bridge Date: 7/24/06
Location: #1 Pavement Elev./Depth:

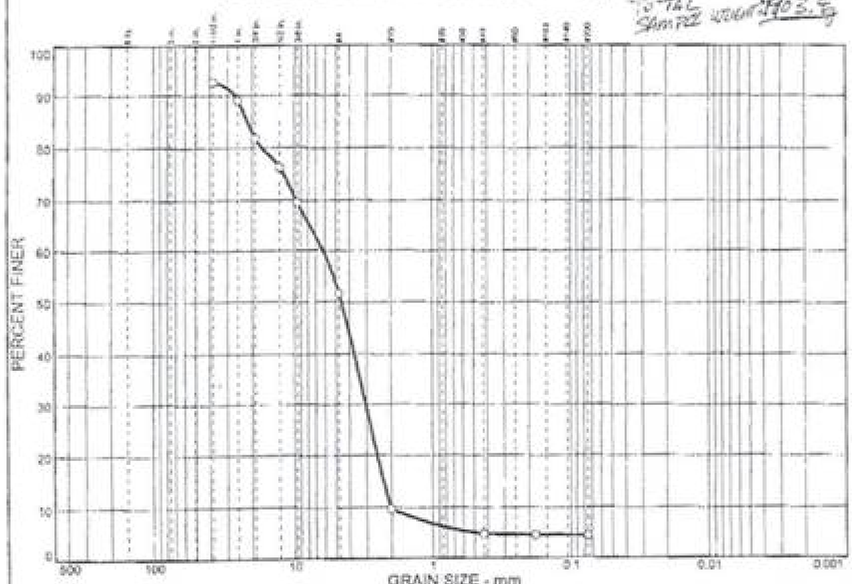
Applied Testing, Inc.
401 E. 4th St., Bridgeport, PA 19405
Phone: 610-313-3227 * Fax: 610-658-0295

Client: F.X. Browne, Inc.
Project: PA1731-01-001
Project No: 506-560 Figure 1

07/26/2006 07:35 6103139567 APPLIED TESTING PAGE 03

Particle Size Distribution Report

Total Sample weight 1903.5 g



% COBBLES	% GRAVEL	% SAND	% SILT	% CLAY
		47.1	4.5	

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
1-1/2 in.	92.6		
1 in.	88.9		
3/4 in.	81.7		
1/2 in.	76.2		
3/8 in.	69.5		
#4	51.6		
#10	9.6		
#40	4.8		
#80	4.6		
#200	4.5		

* (no specification provided)

Soil Description

Atterberg Limits

PL= LL= PI=

Coefficients

D_{85}= 21.8 D_{60}= 6.22 D_{50}= 4.57

D_{30}= 3.06 D_{15}= 2.28 D_{10}= 2.02

C_u= 3.08 C_c= 0.74

Classification

USCS= AASHTO=

Remarks

Sample No.: 1333

Location: #1 Subpavement

Source of Sample: point bar us of railroad bridge

Date: 7/24/06

Elev./Depth:

Applied Testing, Inc.
401 E. 4th St., Bridgeport, PA 19405
Phone: 610-313-3227 * Fax: 610-658-0295

Client: F.X. Browne, Inc.
Project: PA1731-01-001

Project No: 506-360

Figure 2

Appendix C
Peak Flow Calculations

SCS Design storms (Type II).

The total amounts of rainfall for use in the design storms were obtained from the NOAA website http://hdsc.nws.noaa.gov/hdsc/pfds/. At the location (Lat=40.14; Long=-75.1), {Willow grove} the upper 95% confidence gave 5.35 (five point thirty five), 7.50 (seven point fifty), 8.60 (eight point sixty), 11.61 (eleven point sixty one), for the 10, 50, 100, and 500 year storms. The temporal distribution of rainfall pulses for the design storms for the area are of the SCS Type II, whose maximum occurs at the twelfth hour after the beginning of rainfall.

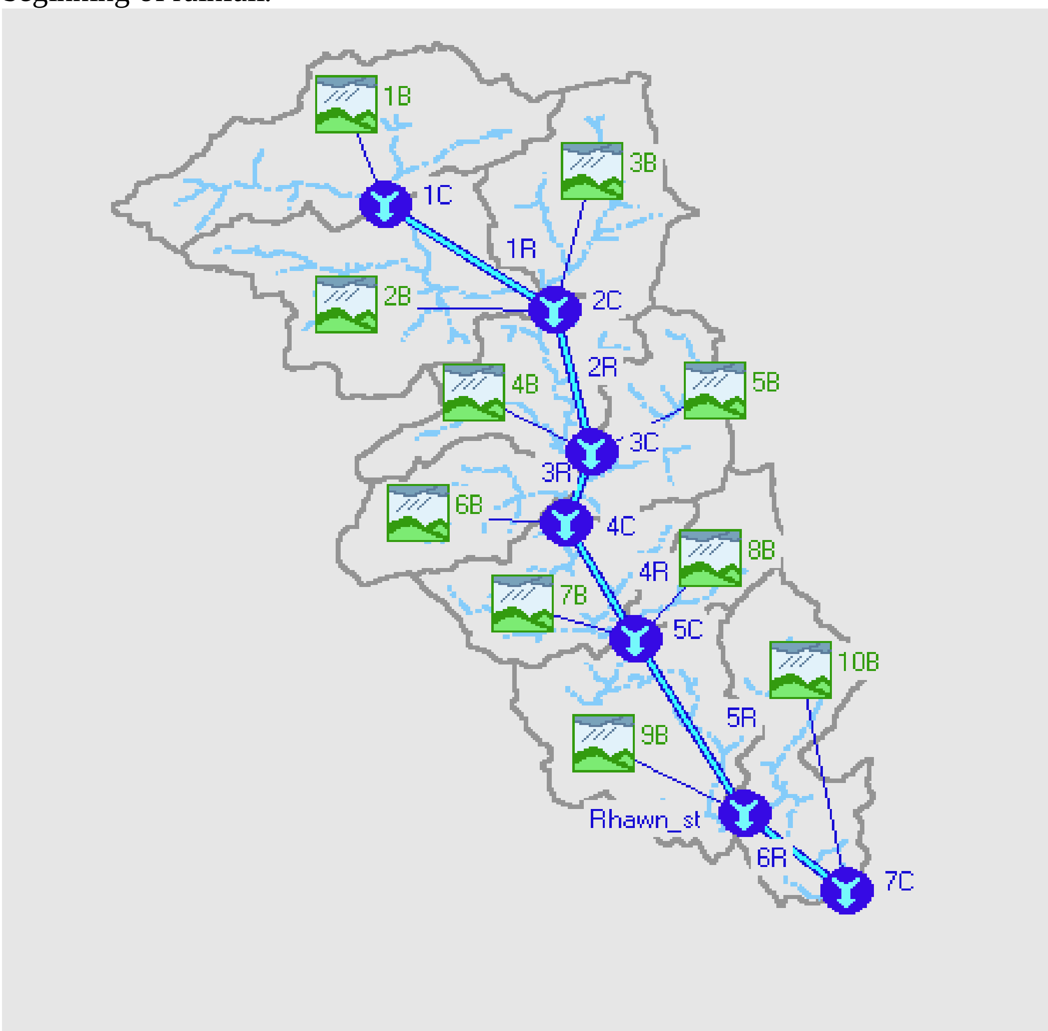


Figure 1: Hydrologic units in the Pennypack Watershed. The study area encompassed seven basins (i.e, 1B through 7B).

Table I-1: Results of the SCS 10-year storm				
Location	Peak flow (cfs)	Date and time	Acre Feet	Drainage Area
1B	3925.2	01 Jul 04 1415	1586.5	8.314
1C	3925.2	01 Jul 04 1415	1586.5	8.314
1R	2976.4	01 Jul 04 1715	1586.5	8.314
2B	3934.1	01 Jul 04 1415	1568.4	7.936
3B	2785.5	01 Jul 04 1415	1062.9	5.963
2C	7493.1	01 Jul 04 1430	4217.8	22.213
2R	6809.9	01 Jul 04 1545	4217.8	22.213
4B	2244.7	01 Jul 04 1345	743.27	4.992
5B	2059.9	01 Jul 04 1400	712.18	4.183
3C	8960	01 Jul 04 1500	5673.2	31.388
3R	8497	01 Jul 04 1615	5673.2	31.388
6B	2199.2	01 Jul 04 1345	671.72	3.941
4C	9079.5	01 Jul 04 1615	6344.9	35.328
4R	8883.7	01 Jul 04 1700	6343.8	35.328
7B	2180.3	01 Jul 04 1400	741.75	4.772
8B	1114.2	01 Jul 04 1430	468.02	2.607
5C	9929.7	01 Jul 04 1645	7553.5	42.708
5R	9551.4	01 Jul 04 1845	7520	42.708
9B	2730.2	01 Jul 04 1445	1265.3	7.123
Rhawn st	10366	01 Jul 04 1830	8785.3	49.831
6R	10101	01 Jul 04 2015	8665.5	49.831
10B	2237.4	01 Jul 04 1515	1225	6.033
7C	10776	01 Jul 04 2000	9890.6	55.864

Table I-2: HEC-HMS Results of the SCS 50-year storm				
Location	Peak flow (cfs)	Date and time	Volume (Acre-Feet)	Drainage Area
1B	6176.7	01 Jul 04 1415	2469.3	8.314
1C	6176.7	01 Jul 04 1415	2469.3	8.314
1R	4902.2	01 Jul 04 1645	2469.3	8.314
2B	6120.1	01 Jul 04 1415	2414.3	7.936
3B	4465.8	01 Jul 04 1415	1681.7	5.963
2C	11701	01 Jul 04 1415	6565.3	22.213
2R	10566	01 Jul 04 1545	6565.3	22.213
4B	3826.7	01 Jul 04 1345	1235.5	4.992
5B	3347.2	01 Jul 04 1400	1142	4.183
3C	13937	01 Jul 04 1500	8942.8	31.388
3R	13361	01 Jul 04 1615	8942.8	31.388
6B	3586	01 Jul 04 1330	1077.4	3.941
4C	14306	01 Jul 04 1600	10020	35.328
4R	14022	01 Jul 04 1700	10019	35.328
7B	3666.3	01 Jul 04 1345	1217.6	4.772
8B	1782.8	01 Jul 04 1430	735.13	2.607
5C	15722	01 Jul 04 1630	11972	42.708
5R	15172	01 Jul 04 1830	11936	42.708
9B	4382.2	01 Jul 04 1445	1987.2	7.123
Rhawn_st	16542	01 Jul 04 1815	13923	49.831
6R	16222	01 Jul 04 1930	13803	49.831
10B	3456.6	01 Jul 04 1515	1863.2	6.033
7C	17406	01 Jul 04 1915	15666	55.864

Table I-3: HEC-HMS results for the SCS 100-year storm				
Location	Peak flow (cfs)	Date and time	Volume Acre Feet	Drainage Area
1B	7344.1	01 Jul 04 1415	2932.1	8.314
1C	7344.1	01 Jul 04 1415	2932.1	8.314
1R	6025.4	01 Jul 04 1630	2932.1	8.314
2B	7252.9	01 Jul 04 1415	2857.1	7.936
3B	5342.3	01 Jul 04 1415	2008.3	5.963
2C	13895	01 Jul 04 1415	7797.5	22.213
2R	12728	01 Jul 04 1545	7797.5	22.213
4B	4665.1	01 Jul 04 1345	1499.1	4.992
5B	4020	01 Jul 04 1400	1369.4	4.183
3C	16902	01 Jul 04 1500	10666	31.388
3R	16441	01 Jul 04 1600	10666	31.388
6B	4311.6	01 Jul 04 1330	1292	3.941
4C	17758	01 Jul 04 1545	11958	35.328
4R	17412	01 Jul 04 1630	11956	35.328
7B	4453.1	01 Jul 04 1345	1471.6	4.772
8B	2136.7	01 Jul 04 1415	876.5	2.607
5C	19845	01 Jul 04 1615	14305	42.708
5R	19108	01 Jul 04 1745	14268	42.708
9B	5254.2	01 Jul 04 1445	2370.2	7.123
Rhawn_st	21209	01 Jul 04 1730	16638	49.831
6R	20843	01 Jul 04 1815	16518	49.831
10B	4093	01 Jul 04 1515	2197.7	6.033
7C	22773	01 Jul 04 1815	18716	55.864

Table I-4: HEC-HMS results of for the SCS 500-year storm				
Location	Peak flow (cfs)	Date and time	Volume Acre Feet	Drainage Area
1B	10551	01 Jul 04 1415	4219.2	8.314
1C	10551	01 Jul 04 1415	4219.2	8.314
1R	9038.2	01 Jul 04 1615	4219.2	8.314
2B	10365	01 Jul 04 1415	4087.7	7.936
3B	7759.3	01 Jul 04 1415	2920.7	5.963
2C	20034	01 Jul 04 1415	11228	22.213
2R	19486	01 Jul 04 1545	11228	22.213
4B	7000.7	01 Jul 04 1345	2243.3	4.992
5B	5876.9	01 Jul 04 1400	2006.3	4.183
3C	26241	01 Jul 04 1500	15477	31.388
3R	25385	01 Jul 04 1545	15477	31.388
6B	6314.7	01 Jul 04 1330	1892.7	3.941
4C	27393	01 Jul 04 1530	17370	35.328
4R	26914	01 Jul 04 1615	17368	35.328
7B	6641.6	01 Jul 04 1345	2187.1	4.772
8B	3120	01 Jul 04 1415	1272.5	2.607
5C	30913	01 Jul 04 1600	20828	42.708
5R	28788	01 Jul 04 1815	20789	42.708
9B	7681.8	01 Jul 04 1445	3445.2	7.123
Rhawn_st	31236	01 Jul 04 1800	24235	49.831
6R	31229	01 Jul 04 1800	24114	49.831
10B	5852.1	01 Jul 04 1515	3128.7	6.033
7C	34691	01 Jul 04 1715	27243	55.864

Appendix D
Hydraulic Calculations Summary

APPENDIX D:
Huntingdon Pike Dam Removal
Hydraulic Calculations Summary

A. Morphology

Bankfull depth (Regional Curves)	**3.4**	ft.	
Bankfull width (Regional Curves)	**68.99**	ft.	
Floodprone width (WinXSPro XS1)	**120.5**	ft.	
Mean depth (WinXSPro XS1)	**2.9**	ft.	
Hydraulic radius (WinXSPro XS1) (at bankfull)	**2.86**	ft.	
Proposed Bed Slope (Lowest slope from long. profile)	**0.0051**		
100 Yr Flow slope (15-20 channel widths)	**0.0041**		
Valley slope (AutoCAD)	**0.0053**		
d84 particle size (pavement/subpavement composite)	**66.5**	mm	
Low flow Manning's n	**0.048**	(Cowan, 1956)	
100Yr flow Manning's n	**0.029**	T&Z	
(WinXSPro)			

20.29			
1.75			
1.29			
C3b			

B. Hydraulics

Bankfull discharge *(From WinXSpro)*	**1309.04**	cfs
V at Bankfull discharge *(From WinXSpro)*	**5.92**	ft./s
Mean shear stress *(From WinXSpro)*	**0.80**	lbs./ft2
Maximum shear stress *(FHA HEC-15)*	**1.08**	lbs./ft2
Bend shear stress *(FHA HEC-15)*	**1.21**	lbs./ft2
Bend radius of curvature *Measured on site plan from CAD.*	**480.65**	ft.
Bottom width *Measured on WinXSPro cross-section diagram for XS-1*	**53.70**	ft.
K ratio (FHA HEC-15)	**8.95**	
K (FHA HEC-15)	**1.12**	

Appendix E
Regional Hydraulic Geometry Curves

Regional Hydraulic Geometry Curves

Huntingdon Pike Dam Removal
F.X.B. Project No. PA1731-01-001
Comparison of bankfull cross-sectional area estimates derived from various regional curve equations
Prepared By: JMD
Date: 7/6/2006
Checked By: SJS
Date: 7/6/2006

Source	Equation for A	R2	Drainage Area (sq mi) (DA)	X-S Area (sq ft) (A)
USGS WRIR 01-4146	11.69*(DA^0.8517)	0.98	35.573	**244.85**
USFWS CBFO-S02-01	17.42*(DA^0.73)	0.95	35.573	**236.25**
USGS SIR 2005-5147 (Chaplin, 2005)	12.04*(DA^0.797)	0.92	35.573	**207.43**
Brown & Moglen, 2000	see urban spreadsheet		35.573	**235.25**
			Avg =	***230.95***

Huntingdon Pike Dam Removal
F.X.B. Project No. PA1731-01-001
Comparison of bankfull width estimates derived from various regional curve equations
Prepared By: JMD
Date: 7/6/2006
Checked By: SJS
Date: 7/6/2006

Source	Equation for W	R2	Drainage Area (sq mi) (DA)	Width (ft) (W)
USGS WRIR 01-4146	14.80*(DA^0.4613)	0.79	35.573	**76.88**
USFWS CBFO-S02-01	14.78*(DA^0.39)	0.83	35.573	**59.51**
USGS SIR 2005-5147 (Chaplin)	14.65*(DA^0.449)	0.81	35.573	**72.83**
Brown & Moglen, 2000	see urban spreadsheet		35.573	**66.74**
			Avg =	***68.99***

Huntingdon Pike Dam Removal
F.X.B. Project No. PA1731-01-001
Comparison of bankfull depth estimates derived from various regional curve equations
Prepared By: JMD
Date: 7/6/2006
Checked By: SJS
Date: 7/6/2006

Source	Equation for d	R2	Drainage Area (sq mi) (DA	Depth (d)
USGS WRIR 01-4146	0.7804*(DA^0.3919)	0.84	35.573	**3.16**
USFWS CBFO-S02-01	1.18*(DA^0.34)	0.88	35.573	**3.97**
USGS SIR 2005-5147 (Chaplin, 2005)	0.875*(DA^0.330)	0.72	35.573	**2.84**
Brown & Moglen, 2000	see urban spreadsheet		35.573	**3.53**
			Avg =	***3.38***

Huntingdon Pike Dam Removal
F.X.B. Project No. PA1731-01-001
Comparison of bankfull cross-sectional area estimates derived from various regional curve equations
Prepared By: JMD
Date: 7/6/2006
Checked By: SJS
Date: 7/6/2006

Source	Equation for A	R2	Drainage Area (sq mi) (DA)	X-S Area (sq ft) (A)
USGS WRIR 01-4146	11.69*(DA^0.8517)	0.98	35.573	**244.85**
USFWS CBFO-S02-01	17.42*(DA^0.73)	0.95	35.573	**236.25**
USGS SIR 2005-5147 (Chaplin, 2005)	12.04*(DA^0.797)	0.92	35.573	**207.43**
Brown & Moglen, 2000	see urban spreadsheet		35.573	**235.25**
			Avg =	***230.95***

Comparison of bankfull cross-sectional area estimates derived from various urban regional curve equations

Project Title: Huntingdon Pike Dam Removal
FXB File No.: PA1731-01-001
Prepared by: JMD
Prepared on: 7/6/2006
Checked by: SJS
Checked on: 7/6/2006

Brown & Moglen

% Forested	% Agriculture	% Urban	Drainage Area sq. mi.	µ	a	Bankfull width ft	Bankful depth ft	XS Area sq. ft
17.68	5.41	74.22	35.573	0.33	43.86	**66.74**	**3.53**	**235.25**

Appendix F
Mannings n Determination

PA1731-01-001
Huntingdon Pike Dam Removal
Manning N Value

Prepared by JMD	Date	7/19/2006
Checked by JLW	Date	8/16/2006

Cross Section 12+55

Stream Channel Manning's N

[1] n=(nb+n1+n2+n3+n4)m

Meandering	m	1.000	from CAD drawing (CL/VL)
base n	nb	0.03	Base n, cobble and boulders
irregularity	n1	0.011	moderate to severe
cross section variation	n2	0.001	mild
obstructions	n3	0.004	negligible
vegetation	n4	0.002	small
Manning's Roughness	**n**	**0.048**	
[1] From USGS Water Supply Paper 2339			
(Cowan, 1956)			

Cross-sectional Area (A) - s.f.	211.66
Wetted Perimeter - P - ft	73.93
Hydraulic Radius - R	2.86
Bed Slope - S (ft/ft)	0.0051
d84 (ft)	0.2182

Limerinos[3]	**0.032493**
n= ((0.0926)R^(1/6))/(1.16+(2.0log(R/d84))	

Jarrett[4]	**0.044346**
n=0.39S^0.38R^-0.16	

[3] Limerinos, 1970
[4] Jarrett, 1984

[2] **Floodplain Manning's N**		
Left Bank	**0.1**	Heavily wooded, minor undergrowth
Right Bank	**0.1**	Heavily wooded, minor undergrowth
[2] From HEC-RAS version 3.1.2 Manning's N Estimation Table		

Jarrett, R.D., "Hydraulics of High Gradient Streams," Journal of Hydraulic Engineering, Vol. 110, No. 11, ASCE, November, 1984).

Limerinos, J.T., Determination of the Manning Coefficient from Measured bed Roughness in Natural Channels,
U.S. Geological Survey Water-Supply Paper 1898-B, 1970.

Cowan, W. L. (1956) Estimating hydraulic roughness coefficients: *Agricultural Engineering* , v. 37, no. 7, p. 473-475.

Appendix G
WinXSPro Uniform Flow Analysis

******************************WinXSPRO********************************
S:\PROJEC~2\PA1731~1\TASK2-~1\WINXSPRO\XS1.OUT
Input File: S:\PROJEC~2\PA1731~1\TASK2-~1\WINXSPRO\XS1_US~1.DAT
Run Date: 08/17/06
Analysis Procedure: Hydraulics
Cross Section Number: 1
Survey Date: 5/25/06

Subsections/Dividing stations
C / 34.50/ A / 112.00/ B / 150.00/ @

Resistance Method: Thorne and Zevenbergen
D84: 66.500 mm

STAGE	#SEC	AREA	PERIM	WIDTH	R	DHYD	SLOPE	n	VAVG	Q	SHEAR
(ft)		(sq ft)	(ft)	(ft)	(ft)	(ft)	(ft/ft)		(ft/s)	(cfs)	(psf)
0.05	T	2.51	50.38	50.37	0.05	0.05	0.005	0.046	0.31	0.77	0.02
0.10	T	5.04	50.77	50.74	0.10	0.10	0.005	0.080	0.28	1.42	0.03
0.15	T	7.58	51.15	51.11	0.15	0.15	0.005	0.092	0.32	2.43	0.05
0.20	T	10.15	51.53	51.48	0.20	0.20	0.005	0.093	0.38	3.87	0.06
0.25	T	12.73	51.91	51.85	0.25	0.25	0.005	0.067	0.62	7.85	0.08
0.30	T	15.33	52.30	52.22	0.29	0.29	0.005	0.060	0.77	11.79	0.09
0.35	T	17.95	52.68	52.59	0.34	0.34	0.005	0.056	0.91	16.41	0.11
0.40	T	20.59	53.06	52.96	0.39	0.39	0.005	0.053	1.05	21.71	0.12
0.45	T	23.25	53.45	53.33	0.44	0.44	0.005	0.051	1.19	27.65	0.13
0.50	T	25.93	53.83	53.70	0.48	0.48	0.005	0.049	1.32	34.21	0.15
0.55	T	28.62	54.21	54.06	0.53	0.53	0.005	0.047	1.45	41.38	0.16
0.60	T	31.33	54.60	54.43	0.57	0.58	0.005	0.046	1.57	49.14	0.18
0.65	T	34.06	54.98	54.80	0.62	0.62	0.005	0.045	1.69	57.49	0.19
0.70	T	36.81	55.36	55.17	0.66	0.67	0.005	0.044	1.80	66.40	0.20
0.75	T	39.58	55.75	55.54	0.71	0.71	0.005	0.043	1.92	75.86	0.22
0.80	T	42.37	56.13	55.91	0.75	0.76	0.005	0.043	2.03	85.87	0.23
0.85	T	45.17	56.51	56.28	0.80	0.80	0.005	0.042	2.13	96.42	0.24
0.90	T	48.00	56.90	56.65	0.84	0.85	0.005	0.041	2.24	107.50	0.26
0.95	T	50.84	57.28	57.02	0.89	0.89	0.005	0.041	2.34	119.09	0.27
1.00	T	53.70	57.66	57.39	0.93	0.94	0.005	0.040	2.44	131.20	0.28
1.05	T	56.58	58.04	57.76	0.97	0.98	0.005	0.040	2.54	143.81	0.29
1.10	T	59.48	58.43	58.13	1.02	1.02	0.005	0.040	2.64	156.93	0.31
1.15	T	62.39	58.81	58.50	1.06	1.07	0.005	0.039	2.73	170.54	0.32
1.20	T	65.33	59.19	58.87	1.10	1.11	0.005	0.039	2.83	184.63	0.33
1.25	T	68.28	59.58	59.24	1.15	1.15	0.005	0.039	2.92	199.21	0.34
1.30	T	71.25	59.96	59.61	1.19	1.20	0.005	0.038	3.01	214.27	0.36

1.35	T	74.24	60.34	59.98	1.23	1.24	0.005	0.038	3.10	229.81	0.37
1.40	T	77.25	60.73	60.35	1.27	1.28	0.005	0.038	3.18	245.81	0.38
1.45	T	80.27	61.11	60.72	1.31	1.32	0.005	0.038	3.27	262.28	0.39
1.50	T	83.32	61.49	61.09	1.35	1.36	0.005	0.038	3.35	279.21	0.40
1.55	T	86.38	61.88	61.46	1.40	1.41	0.005	0.037	3.43	296.60	0.41
1.60	T	89.47	62.26	61.83	1.44	1.45	0.005	0.037	3.51	314.44	0.43
1.65	T	92.57	62.64	62.20	1.48	1.49	0.005	0.037	3.59	332.74	0.44
1.70	T	95.69	63.03	62.57	1.52	1.53	0.005	0.037	3.67	351.48	0.45
1.75	T	98.82	63.41	62.94	1.56	1.57	0.005	0.037	3.75	370.67	0.46
1.80	T	101.98	63.79	63.31	1.60	1.61	0.005	0.037	3.83	390.30	0.47
1.85	T	105.16	64.17	63.68	1.64	1.65	0.005	0.036	3.90	410.37	0.48
1.90	T	108.35	64.56	64.05	1.68	1.69	0.005	0.036	3.98	430.88	0.49
1.95	T	111.56	64.94	64.41	1.72	1.73	0.005	0.036	4.05	451.83	0.50
2.00	T	114.79	65.32	64.78	1.76	1.77	0.005	0.036	4.12	473.20	0.51
2.05	T	118.04	65.71	65.15	1.80	1.81	0.005	0.036	4.19	495.01	0.52
2.10	T	121.31	66.09	65.52	1.84	1.85	0.005	0.036	4.26	517.25	0.54
2.15	T	124.59	66.47	65.89	1.87	1.89	0.005	0.036	4.33	539.91	0.55
2.20	T	127.90	66.86	66.26	1.91	1.93	0.005	0.036	4.40	563.00	0.56
2.25	T	131.22	67.24	66.63	1.95	1.97	0.005	0.035	4.47	586.50	0.57
2.30	T	134.56	67.62	67.00	1.99	2.01	0.005	0.035	4.54	610.43	0.58
2.35	T	137.92	68.01	67.37	2.03	2.05	0.005	0.035	4.60	634.78	0.59
2.40	T	141.30	68.39	67.74	2.07	2.09	0.005	0.035	4.67	659.55	0.60
2.45	T	144.69	68.67	68.00	2.11	2.13	0.005	0.035	4.74	685.41	0.61
2.50	T	148.10	68.95	68.27	2.15	2.17	0.005	0.035	4.81	711.68	0.62
2.55	T	151.52	69.24	68.53	2.19	2.21	0.005	0.035	4.87	738.37	0.63
2.60	T	154.95	69.52	68.79	2.23	2.25	0.005	0.035	4.94	765.46	0.64
2.65	T	158.40	69.80	69.06	2.27	2.29	0.005	0.035	5.01	792.96	0.65

2.70	T	161.86	70.08	69.32	2.31	2.33	0.005	0.035	5.07	820.86
0.66										
2.75	T	165.33	70.36	69.58	2.35	2.38	0.005	0.035	5.14	849.16
0.67										
2.80	T	168.82	70.65	69.85	2.39	2.42	0.005	0.035	5.20	877.86
0.68										
2.85	T	172.32	70.93	70.11	2.43	2.46	0.005	0.035	5.26	906.96
0.69										
2.90	T	175.83	71.21	70.37	2.47	2.50	0.005	0.034	5.33	936.45
0.70										
2.95	T	179.35	71.49	70.64	2.51	2.54	0.005	0.034	5.39	966.33
0.71										
3.00	T	182.89	71.78	70.90	2.55	2.58	0.005	0.034	5.45	996.60
0.72										
3.05	T	186.44	72.06	71.16	2.59	2.62	0.005	0.034	5.51	1027.26
0.73										
3.10	T	190.01	72.34	71.43	2.63	2.66	0.005	0.034	5.57	1058.30
0.74										
3.15	T	193.59	72.61	71.67	2.67	2.70	0.005	0.034	5.63	1089.90
0.75										
3.20	T	197.18	72.87	71.91	2.71	2.74	0.004	0.034	5.69	1121.89
0.76										
3.25	T	200.78	73.14	72.16	2.75	2.78	0.004	0.034	5.75	1154.25
0.77										
3.30	T	204.39	73.40	72.40	2.78	2.82	0.004	0.034	5.81	1186.99
0.78										
3.35	T	208.02	73.67	72.65	2.82	2.86	0.004	0.034	5.87	1220.10
0.79										
3.40	T	211.66	73.93	72.89	2.86	2.90	0.004	0.034	5.92	1253.59
0.80										
3.45	T	215.31	74.19	73.14	2.90	2.94	0.004	0.034	5.98	1287.44
0.81										
3.50	T	218.97	74.46	73.38	2.94	2.98	0.004	0.034	6.04	1321.67
0.82										
3.55	T	222.65	74.72	73.63	2.98	3.02	0.004	0.034	6.09	1356.26
0.83										
3.60	T	226.33	74.99	73.87	3.02	3.06	0.004	0.034	6.15	1391.22
0.84										
3.65	T	230.03	75.25	74.12	3.06	3.10	0.004	0.034	6.20	1426.54
0.84										
3.70	T	233.75	75.52	74.36	3.10	3.14	0.004	0.034	6.26	1462.22
0.85										
3.75	T	237.47	75.78	74.61	3.13	3.18	0.004	0.034	6.31	1498.26
0.86										
3.80	A	241.21	76.05	74.85	3.17	3.22	0.004	0.034	6.36	1534.67
0.87										

3.80	B	0.00	0.02	0.02	0.00	0.00	0.004	0.103	0.00	0.00		0.00
3.80	T	241.21	76.07	74.87	3.17	3.22	0.004	0.034	6.36	1534.67		0.87
3.85	A	244.95	76.16	74.95	3.22	3.27	0.004	0.034	6.42	1573.50		0.88
3.85	B	0.10	4.02	4.02	0.03	0.03	0.004	0.088	0.10	0.01		0.01
3.85	T	245.05	80.18	78.97	3.06	3.10	0.004	0.032	6.42	1573.51		0.84
3.90	A	248.70	76.28	75.05	3.26	3.31	0.004	0.033	6.48	1612.69		0.89
3.90	B	0.40	8.02	8.02	0.05	0.05	0.004	0.086	0.16	0.06		0.01
3.90	T	249.11	84.30	83.08	2.96	3.00	0.004	0.031	6.47	1612.75		0.81
3.95	A	252.46	76.39	75.16	3.30	3.36	0.004	0.033	6.54	1652.24		0.90
3.95	B	0.93	13.02	13.02	0.07	0.07	0.004	0.083	0.20	0.19		0.02
3.95	T	253.39	89.41	88.18	2.83	2.87	0.004	0.030	6.52	1652.43		0.78
4.00	A	256.22	76.50	75.26	3.35	3.40	0.004	0.033	6.60	1692.15		0.91
4.00	B	1.71	38.00	38.00	0.04	0.04	0.004	0.046	0.27	0.46	*	0.01
4.00	T	257.93	114.50	113.26	2.25	2.28	0.004	0.026	6.56	1692.61	*	0.61
4.05	A	259.99	76.62	75.36	3.39	3.45	0.004	0.033	6.66	1732.41		0.92
4.05	B	3.61	38.05	38.00	0.09	0.09	0.004	0.080	0.26	0.93	*	0.03
4.05	T	263.60	114.67	113.36	2.30	2.33	0.004	0.026	6.58	1733.34	*	0.63
4.10	A	263.76	76.73	75.46	3.44	3.50	0.004	0.033	6.72	1773.03		0.94
4.10	B	5.51	38.10	38.00	0.14	0.14	0.004	0.088	0.31	1.69	*	0.04
4.10	T	269.27	114.83	113.46	2.34	2.37	0.004	0.026	6.59	1774.72	*	0.64
4.15	A	267.53	76.84	75.56	3.48	3.54	0.004	0.033	6.78	1814.00		0.95
4.15	B	7.41	38.15	38.00	0.19	0.19	0.004	0.087	0.38	2.81	*	0.05
4.15	T	274.94	114.99	113.56	2.39	2.42	0.004	0.027	6.61	1816.81	*	0.65
4.20	A	271.31	76.96	75.67	3.53	3.59	0.004	0.033	6.84	1855.31		0.96
4.20	B	9.31	38.20	38.00	0.24	0.24	0.004	0.060	0.64	5.96	*	0.07
4.20	T	280.62	115.16	113.66	2.44	2.47	0.004	0.027	6.63	1861.27	*	0.66
4.25	A	275.10	77.07	75.77	3.57	3.63	0.004	0.033	6.90	1896.97		0.97
4.25	B	11.21	38.25	38.00	0.29	0.29	0.004	0.055	0.78	8.76	*	0.08

4.25	T	286.31	115.32	113.77	2.48	2.52	0.004	0.027	6.66	1905.73	*	0.67
4.30	A	278.89	77.18	75.87	3.61	3.68	0.004	0.033	6.95	1938.97		0.98
4.30	B	13.11	38.30	38.00	0.34	0.34	0.004	0.052	0.92	12.04	*	0.09
4.30	T	292.00	115.48	113.87	2.53	2.56	0.004	0.027	6.68	1951.01	*	0.68
4.35	A	282.69	77.30	75.97	3.66	3.72	0.004	0.033	7.01	1981.30		0.99
4.35	B	15.01	38.35	38.00	0.39	0.40	0.004	0.050	1.05	15.77	*	0.11
4.35	T	297.70	115.65	113.97	2.57	2.61	0.004	0.027	6.71	1997.07	*	0.69
4.40	A	286.49	77.41	76.07	3.70	3.77	0.004	0.033	7.06	2023.98		1.00
4.40	B	16.91	38.40	38.00	0.44	0.44	0.004	0.048	1.18	19.93	*	0.12
4.40	T	303.40	115.81	114.07	2.62	2.66	0.004	0.028	6.74	2043.91	*	0.70
4.45	A	290.29	77.52	76.17	3.74	3.81	0.004	0.033	7.12	2066.99		1.01
4.45	B	18.81	38.45	38.00	0.49	0.50	0.004	0.047	1.30	24.51	*	0.13
4.45	T	309.10	115.97	114.17	2.67	2.71	0.004	0.028	6.77	2091.49	*	0.72
4.50	A	294.11	77.64	76.28	3.79	3.86	0.004	0.033	7.18	2110.32		1.02
4.50	B	20.71	38.50	38.00	0.54	0.55	0.004	0.045	1.42	29.49	*	0.14
4.50	T	314.82	116.14	114.28	2.71	2.75	0.004	0.028	6.80	2139.81	*	0.73
4.55	A	297.92	77.75	76.38	3.83	3.90	0.004	0.033	7.23	2153.99		1.03
4.55	B	22.61	38.55	38.00	0.59	0.60	0.004	0.044	1.54	34.86	*	0.16
4.55	T	320.53	116.30	114.38	2.76	2.80	0.004	0.028	6.83	2188.85	*	0.74
4.60	A	301.74	77.86	76.48	3.88	3.95	0.004	0.033	7.28	2197.98		1.04
4.60	B	24.51	38.60	38.00	0.63	0.65	0.004	0.043	1.66	40.60	*	0.17
4.60	T	326.25	116.46	114.48	2.80	2.85	0.004	0.028	6.86	2238.59	*	0.75
4.65	A	305.57	77.98	76.58	3.92	3.99	0.004	0.033	7.34	2242.30		1.04

4.65	B	26.41	38.65	38.00	0.68	0.70	0.004	0.043	1.77	46.71	*	0.18
4.65	T	331.98	116.63	114.58	2.85	2.90	0.004	0.028	6.90	2289.01	*	0.76
4.70	A	309.40	78.09	76.68	3.96	4.03	0.004	0.033	7.39	2286.94		1.05
4.70	B	28.31	38.70	38.00	0.73	0.75	0.004	0.042	1.88	53.18	*	0.19
4.70	T	337.71	116.79	114.68	2.89	2.94	0.004	0.029	6.93	2340.12	*	0.77
4.75	A	313.24	78.20	76.79	4.01	4.08	0.004	0.033	7.44	2331.89		1.06
4.75	B	30.21	38.75	38.00	0.78	0.80	0.004	0.041	1.99	59.99	*	0.21
4.75	T	343.45	116.95	114.79	2.94	2.99	0.004	0.029	6.96	2391.88	*	0.78
4.80	A	317.08	78.32	76.89	4.05	4.12	0.004	0.033	7.50	2377.16		1.07
4.80	B	32.11	38.80	38.00	0.83	0.85	0.004	0.041	2.09	67.14	*	0.22
4.80	T	349.19	117.12	114.89	2.98	3.04	0.004	0.029	7.00	2444.30	*	0.79
4.85	A	320.93	78.43	76.99	4.09	4.17	0.004	0.033	7.55	2422.75		1.08
4.85	B	34.01	38.85	38.00	0.88	0.90	0.004	0.040	2.19	74.62	*	0.23
4.85	T	354.94	117.28	114.99	3.03	3.09	0.004	0.029	7.04	2497.37	*	0.80
4.90	A	324.78	78.54	77.09	4.14	4.21	0.004	0.033	7.60	2468.64		1.09
4.90	B	35.91	38.90	38.00	0.92	0.95	0.004	0.040	2.30	82.42	*	0.24
4.90	T	360.69	117.44	115.09	3.07	3.13	0.004	0.029	7.07	2551.06	*	0.81
4.95	A	328.64	78.66	77.19	4.18	4.26	0.004	0.033	7.65	2514.85		1.10
4.95	B	37.81	38.95	38.00	0.97	1.00	0.004	0.040	2.39	90.53	*	0.26
4.95	T	366.45	117.61	115.19	3.12	3.18	0.004	0.029	7.11	2605.38	*	0.82
5.00	A	332.50	78.77	77.30	4.22	4.30	0.004	0.033	7.70	2561.36		1.11
5.00	B	39.71	39.00	38.00	1.02	1.05	0.004	0.039	2.49	98.95	*	0.27
5.00	T	372.21	117.77	115.29	3.16	3.23	0.004	0.029	7.15	2660.31	*	0.83

5.05	A	336.37	78.88	77.40	4.26	4.35	0.004	0.033	7.75	2608.17		1.12
5.05	B	41.61	39.05	38.00	1.07	1.10	0.004	0.039	2.59	107.67	*	0.28
5.05	T	377.98	117.94	115.40	3.20	3.28	0.004	0.029	7.19	2715.84	*	0.84
5.10	A	340.24	79.00	77.50	4.31	4.39	0.004	0.033	7.80	2655.30		1.13
5.10	B	43.51	39.10	38.00	1.11	1.15	0.004	0.039	2.68	116.68	*	0.29
5.10	C	0.00	4.51	4.51	0.00	0.00	0.004	0.000	315.23	0.44		0.00
5.10	T	383.75	122.60	120.00	3.13	3.20	0.004	0.029	7.22	2772.43	*	0.82
5.15	A	344.12	79.00	77.50	4.36	4.44	0.004	0.033	7.86	2705.26		1.14
5.15	B	45.41	39.15	38.00	1.16	1.20	0.004	0.038	2.77	125.98	*	0.30
5.15	C	0.25	5.51	5.51	0.05	0.05	0.004	0.096	0.13	0.03		0.01
5.15	T	389.78	123.66	121.00	3.15	3.22	0.004	0.029	7.26	2831.27	*	0.83
5.20	A	347.99	79.00	77.50	4.41	4.49	0.004	0.033	7.92	2755.53		1.15
5.20	B	47.31	39.20	38.00	1.21	1.25	0.004	0.038	2.87	135.55	*	0.32
5.20	C	0.55	6.51	6.51	0.08	0.08	0.004	0.092	0.20	0.11		0.02
5.20	T	395.85	124.71	122.00	3.17	3.24	0.004	0.029	7.30	2891.20	*	0.83
5.25	A	351.87	79.00	77.50	4.45	4.54	0.004	0.033	7.97	2806.12		1.16
5.25	B	49.21	39.25	38.00	1.25	1.30	0.004	0.038	2.95	145.41	*	0.33
5.25	C	0.90	7.51	7.51	0.12	0.12	0.004	0.081	0.29	0.26		0.03
5.25	T	401.98	125.76	123.00	3.20	3.27	0.004	0.028	7.34	2951.79	*	0.83
5.30	A	355.74	79.00	77.50	4.50	4.59	0.004	0.033	8.03	2857.02		1.17
5.30	B	51.11	39.30	38.00	1.30	1.35	0.004	0.038	3.04	155.53	*	0.34
5.30	C	1.30	8.51	8.51	0.15	0.15	0.004	0.072	0.38	0.50		0.04
5.30	T	408.16	126.81	124.00	3.22	3.29	0.004	0.028	7.38	3013.05	*	0.84
5.35	A	359.62	79.00	77.50	4.55	4.64	0.004	0.033	8.09	2908.22		1.18
5.35	B	53.01	39.35	38.00	1.35	1.40	0.004	0.037	3.13	165.92	*	0.35
5.35	C	1.75	9.51	9.51	0.18	0.18	0.004	0.065	0.48	0.84		0.05

5.35	T	414.38	127.86	125.00	3.24	3.31	0.004	0.028	7.42	3074.98	*	0.84
5.40	A	363.49	79.00	77.50	4.60	4.69	0.004	0.033	8.14	2959.73		1.19
5.40	B	54.91	39.40	38.00	1.39	1.45	0.004	0.037	3.22	176.57	*	0.36
5.40	C	2.25	10.51	10.51	0.21	0.21	0.004	0.059	0.58	1.31		0.06
5.40	T	420.66	128.91	126.00	3.26	3.34	0.004	0.028	7.46	3137.61	*	0.85
5.45	A	367.37	79.00	77.50	4.65	4.74	0.004	0.033	8.20	3011.54		1.20
5.45	B	56.81	39.45	38.00	1.44	1.50	0.004	0.037	3.30	187.47	*	0.37
5.45	C	2.80	11.52	11.51	0.24	0.24	0.004	0.062	0.61	1.70		0.06
5.45	T	426.98	129.96	127.00	3.29	3.36	0.004	0.028	7.50	3200.72	*	0.85
5.50	A	371.24	79.00	77.50	4.70	4.79	0.004	0.033	8.25	3063.65		1.21
5.50	B	58.71	39.50	38.00	1.49	1.55	0.004	0.037	3.38	198.63	*	0.38
5.50	C	3.40	12.52	12.51	0.27	0.27	0.004	0.058	0.69	2.37		0.07
5.50	T	433.36	131.01	128.00	3.31	3.39	0.004	0.028	7.53	3264.65	*	0.85
5.55	A	375.12	79.00	77.50	4.75	4.84	0.004	0.033	8.31	3116.06		1.22
5.55	B	60.61	39.55	38.00	1.53	1.60	0.004	0.037	3.47	210.03	*	0.40
5.55	C	4.05	13.52	13.51	0.30	0.30	0.004	0.055	0.78	3.16		0.08
5.55	T	439.78	132.07	129.00	3.33	3.41	0.004	0.028	7.57	3329.25	*	0.86
5.60	A	378.99	79.00	77.50	4.80	4.89	0.004	0.033	8.36	3168.76		1.23
5.60	B	62.51	39.60	38.00	1.58	1.65	0.004	0.037	3.55	221.67	*	0.41
5.60	C	4.75	14.52	14.50	0.33	0.33	0.004	0.053	0.86	4.10		0.08
5.60	T	446.26	133.11	130.00	3.35	3.43	0.004	0.028	7.61	3394.53	*	0.86
5.65	A	382.87	79.00	77.50	4.85	4.94	0.004	0.033	8.41	3221.75		1.25
5.65	B	64.41	39.65	38.00	1.62	1.70	0.004	0.036	3.63	233.55	*	0.42
5.65	C	5.50	15.14	15.13	0.36	0.36	0.004	0.051	0.96	5.28		0.09
5.65	T	452.78	133.79	130.63	3.38	3.47	0.004	0.028	7.64	3460.57	*	0.87
5.70	A	386.74	79.00	77.50	4.90	4.99	0.004	0.033	8.47	3275.03		1.26

5.70	B	66.31	39.70	38.00	1.67	1.75	0.004	0.036	3.70	245.66	*	0.43
5.70	C	6.27	15.77	15.75	0.40	0.40	0.004	0.049	1.05	6.60		0.10
5.70	T	459.32	134.47	131.25	3.42	3.50	0.004	0.028	7.68	3527.30	*	0.88
5.75	A	390.62	79.00	77.50	4.94	5.04	0.004	0.032	8.52	3328.59		1.27
5.75	B	68.21	39.75	38.00	1.72	1.80	0.004	0.036	3.78	258.01	*	0.44
5.75	C	7.07	16.40	16.38	0.43	0.43	0.004	0.048	1.14	8.09		0.11
5.75	T	465.90	135.15	131.88	3.45	3.53	0.004	0.028	7.72	3594.69	*	0.88
5.80	A	394.49	79.00	77.50	4.99	5.09	0.004	0.032	8.57	3382.44		1.28
5.80	B	70.11	39.80	38.00	1.76	1.85	0.004	0.036	3.86	270.57	*	0.45
5.80	C	7.91	17.02	17.00	0.46	0.46	0.004	0.046	1.23	9.73		0.12
5.80	T	472.51	135.82	132.50	3.48	3.57	0.004	0.028	7.75	3662.74	*	0.89
5.85	A	398.37	79.00	77.50	5.04	5.14	0.004	0.032	8.63	3436.56		1.29
5.85	B	72.01	39.85	38.00	1.81	1.90	0.004	0.036	3.93	283.36	*	0.46
5.85	C	8.77	17.65	17.63	0.50	0.50	0.004	0.045	1.31	11.53		0.13
5.85	T	479.15	136.50	133.13	3.51	3.60	0.004	0.028	7.79	3731.45	*	0.89
5.90	A	402.24	79.00	77.50	5.09	5.19	0.004	0.032	8.68	3490.97		1.30
5.90	B	73.91	39.90	38.00	1.85	1.95	0.004	0.036	4.01	296.37	*	0.47
5.90	C	9.67	18.28	18.25	0.53	0.53	0.004	0.045	1.40	13.49		0.13
5.90	T	485.82	137.18	133.75	3.54	3.63	0.004	0.028	7.82	3800.83	*	0.90
5.95	A	406.12	79.00	77.50	5.14	5.24	0.004	0.032	8.73	3545.65		1.31
5.95	B	75.81	39.95	38.00	1.90	2.00	0.004	0.036	4.08	309.59	*	0.48
5.95	C	10.60	18.91	18.88	0.56	0.56	0.004	0.044	1.47	15.62		0.14
5.95	T	492.53	137.85	134.38	3.57	3.67	0.004	0.028	7.86	3870.85	*	0.91
6.00	A	409.99	79.00	77.50	5.19	5.29	0.004	0.032	8.78	3600.60		1.32
6.00	B	77.71	40.00	38.00	1.94	2.05	0.004	0.036	4.16	323.03	*	0.49
6.00	C	11.56	19.54	19.51	0.59	0.59	0.004	0.043	1.55	17.91	*	0.15

6.00	T	499.26	138.54	135.01	3.60	3.70	0.004	0.028	7.89	3941.53	*	0.91
6.05	A	413.87	79.00	77.50	5.24	5.34	0.004	0.032	8.83	3655.82		1.33
6.05	B	79.61	40.05	38.00	1.99	2.10	0.004	0.035	4.23	336.67	*	0.50
6.05	C	12.58	21.47	21.39	0.59	0.59	0.004	0.043	1.55	19.47	*	0.15
6.05	T	506.06	140.52	136.89	3.60	3.70	0.004	0.028	7.93	4011.95	*	0.91
6.10	A	417.74	79.00	77.50	5.29	5.39	0.004	0.032	8.88	3711.30		1.34
6.10	B	81.51	40.10	38.00	2.03	2.15	0.004	0.035	4.30	350.51	*	0.51
6.10	C	13.70	23.40	23.26	0.59	0.59	0.004	0.043	1.56	21.31	*	0.15
6.10	T	512.95	142.50	138.76	3.60	3.70	0.004	0.028	7.96	4083.12	*	0.91
6.15	A	421.62	79.00	77.50	5.34	5.44	0.004	0.032	8.93	3767.05		1.35
6.15	B	83.41	40.15	38.00	2.08	2.20	0.004	0.035	4.37	364.56	*	0.52
6.15	C	14.91	25.33	25.14	0.59	0.59	0.004	0.042	1.57	23.43	*	0.15
6.15	T	519.94	144.47	140.64	3.60	3.70	0.004	0.028	7.99	4155.04	*	0.91
6.20	A	425.49	79.00	77.50	5.39	5.49	0.004	0.032	8.98	3823.07		1.35
6.20	B	85.31	40.20	38.00	2.12	2.25	0.004	0.035	4.44	378.80	*	0.53
6.20	C	16.21	27.25	27.01	0.59	0.60	0.004	0.042	1.59	25.82	*	0.15
6.20	T	527.02	146.45	142.51	3.60	3.70	0.004	0.028	8.02	4227.69	*	0.91
6.25	A	429.37	79.00	77.50	5.44	5.54	0.004	0.032	9.03	3879.34		1.36
6.25	B	87.21	40.25	38.00	2.17	2.30	0.004	0.035	4.51	393.24	*	0.54
6.25	C	17.61	29.18	28.89	0.60	0.61	0.004	0.042	1.62	28.51	*	0.15
6.25	T	534.19	148.43	144.39	3.60	3.70	0.004	0.028	8.05	4301.09	*	0.90
6.30	A	433.25	79.00	77.50	5.48	5.59	0.004	0.032	9.08	3935.87		1.37
6.30	B	89.11	40.30	38.00	2.21	2.35	0.004	0.035	4.58	407.87	*	0.55

6.30	C	19.10	31.11	30.76	0.61	0.62	0.004	0.041	1.65	31.50	*	0.15
6.30	T	541.46	150.41	146.26	3.60	3.70	0.004	0.027	8.08	4375.24	*	0.90
6.35	A	437.12	79.00	77.50	5.53	5.64	0.004	0.032	9.13	3992.65		1.38
6.35	B	91.01	40.35	38.00	2.26	2.40	0.004	0.035	4.64	422.69	*	0.56
6.35	C	20.68	33.04	32.64	0.63	0.63	0.004	0.041	1.68	34.79	*	0.16
6.35	T	548.82	152.39	148.14	3.60	3.70	0.004	0.027	8.11	4450.14	*	0.90
6.40	A	440.97	79.00	77.50	5.58	5.69	0.004	0.032	9.18	4049.24		1.39
6.40	B	92.90	40.40	38.00	2.30	2.44	0.004	0.035	4.71	437.58	*	0.57
6.40	C	22.35	34.95	34.50	0.64	0.65	0.004	0.041	1.72	38.37	*	0.16
6.40	T	556.21	154.35	150.00	3.60	3.71	0.004	0.027	8.14	4525.20	*	0.90

STAGE	ALPHA	FROUDE
0.05	1.00	0.24
0.10	1.00	0.16
0.15	1.00	0.15
0.20	1.00	0.15
0.25	1.00	0.22
0.30	1.00	0.25
0.35	1.00	0.28
0.40	1.00	0.30
0.45	1.00	0.32
0.50	1.00	0.33
0.55	1.00	0.35
0.60	1.00	0.36
0.65	1.00	0.38
0.70	1.00	0.39
0.75	1.00	0.40
0.80	1.00	0.41
0.85	1.00	0.42
0.90	1.00	0.43
0.95	1.00	0.44
1.00	1.00	0.45
1.05	1.00	0.45
1.10	1.00	0.46
1.15	1.00	0.47
1.20	1.00	0.47

1.25	1.00	0.48
1.30	1.00	0.48
1.35	1.00	0.49
1.40	1.00	0.50
1.45	1.00	0.50
1.50	1.00	0.51
1.55	1.00	0.51
1.60	1.00	0.51
1.65	1.00	0.52
1.70	1.00	0.52
1.75	1.00	0.53
1.80	1.00	0.53
1.85	1.00	0.54
1.90	1.00	0.54
1.95	1.00	0.54
2.00	1.00	0.55
2.05	1.00	0.55
2.10	1.00	0.55
2.15	1.00	0.56
2.20	1.00	0.56
2.25	1.00	0.56
2.30	1.00	0.56
2.35	1.00	0.57
2.40	1.00	0.57
2.45	1.00	0.57
2.50	1.00	0.57
2.55	1.00	0.58
2.60	1.00	0.58
2.65	1.00	0.58
2.70	1.00	0.58
2.75	1.00	0.59
2.80	1.00	0.59
2.85	1.00	0.59
2.90	1.00	0.59
2.95	1.00	0.60
3.00	1.00	0.60
3.05	1.00	0.60
3.10	1.00	0.60
3.15	1.00	0.60
3.20	1.00	0.61
3.25	1.00	0.61
3.30	1.00	0.61
3.35	1.00	0.61
3.40	1.00	0.61
3.45	1.00	0.61
3.50	1.00	0.62

3.55	1.00	0.62
3.60	1.00	0.62
3.65	1.00	0.62
3.70	1.00	0.62
3.75	1.00	0.62
3.80	1.00	0.62
3.85	1.00	0.64
3.90	1.00	0.66
3.95	1.01	0.68
4.00	1.01	0.77
4.05	1.03	0.76
4.10	1.04	0.75
4.15	1.05	0.75
4.20	1.06	0.74
4.25	1.07	0.74
4.30	1.08	0.74
4.35	1.08	0.73
4.40	1.09	0.73
4.45	1.09	0.72
4.50	1.10	0.72
4.55	1.10	0.72
4.60	1.11	0.72
4.65	1.11	0.71
4.70	1.11	0.71
4.75	1.12	0.71
4.80	1.12	0.71
4.85	1.12	0.71
4.90	1.12	0.70
4.95	1.12	0.70
5.00	1.12	0.70
5.05	1.12	0.70
5.10	1.12	0.71
5.15	1.13	0.71
5.20	1.13	0.71
5.25	1.13	0.72
5.30	1.13	0.72
5.35	1.13	0.72
5.40	1.13	0.72
5.45	1.14	0.72
5.50	1.14	0.72
5.55	1.14	0.72
5.60	1.14	0.72
5.65	1.14	0.72
5.70	1.15	0.72
5.75	1.15	0.72
5.80	1.15	0.72

5.85	1.15	0.72
5.90	1.15	0.72
5.95	1.15	0.72
6.00	1.15	0.72
6.05	1.16	0.73
6.10	1.16	0.73
6.15	1.16	0.73
6.20	1.16	0.74
6.25	1.16	0.74
6.30	1.17	0.74
6.35	1.17	0.74
6.40	1.17	0.74

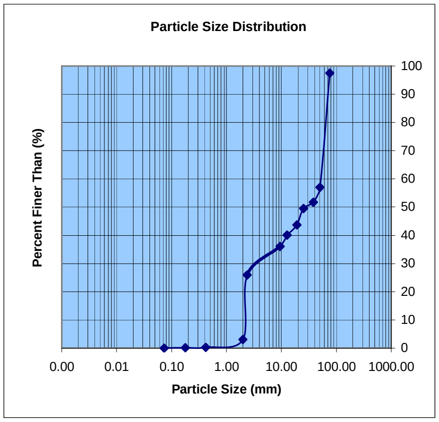
Appendix H
Sediment Incipient Motion Validation

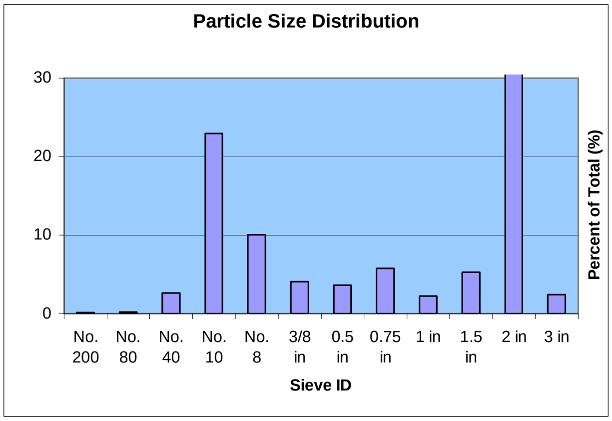
F. X. Browne, Inc.

F.X.B. Project No. PA1731-01-001
Composite Sample Sieve Analysis
Comparison of bankfull discharge estimates derived from various regional curve equations
Prepared By: JMD
Date: 8/3/2006
Checked By: DIS
Date: 8/16/2006

Sieve ID	Sieve Size (in)	Sieve Size (mm)	Wetted Material Only (g)	Percent of Total	Percent Finer	Decimal Percent Finer
No. 200	0.003	0.074	4.985553	0.143	0.000	0.000
No. 80	0.007	0.178	6.904741	0.198	0.143	0.001
No. 40	0.017	0.419	92.94719	2.662	0.340	0.003
No. 10	0.079	1.999	800.9748	22.937	3.002	0.030
No. 8	0.094	2.380	351.8122	10.075	25.939	0.259
3/8 in	0.375	9.525	141.8202	4.061	36.014	0.360
0.5 in	0.500	12.700	126.9246	3.635	40.075	0.401
0.75 in	0.750	19.050	202.178	5.790	43.710	0.437
1 in	1.000	25.400	78.36605	2.244	49.499	0.495
1.5 in	1.500	38.100	183.7415	5.262	51.743	0.517
2 in	2.000	50.800	1415.612	40.538	57.005	0.570
3 in	3.000	76.200	85.80738	2.457	97.543	0.975
Total			3492.07	100.00		1
				100		

	mm	in
$D_{90=}$	70.66267	2.781995
$D_{84=}$	66.54674	2.61995
$D_{60=}$	52.34484	2.06082
$D_{50=}$	27.8057	1.094713
$D_{30=}$	4.162436	0.163875
$D_{16=}$	1.853437	0.07297





Appendix I
Riprap Toe Sizing Calculations

Huntingdon Pike Dam Removal
Riprap Toe Sizing
FXB #: PA1731-01-001

Prepared by: JMD Date 7/25/2006 0:00
Spreadsheet checked by: Date

Specific gravity 2.65

Isbash method	D100 =	3.20	inches	x	2	6.40	inches		

FHA method	D50 =	5.36	inches	*FHA design factors*				
(HEC 11)				SF=	1.70	Design bank angle	18.4	degrees
				Csf=	1.68	Angle of Repose	40	degrees

FWS method	D75=	6.42	inches	*FWS design factors*			
				C=	0.75	K=	0.87

NCSA Class size	**R-3**	x SF (2")	**R-4**	Riprap Class to be used

Isbash estimates are doubled as recommended by the NRCS Engineering Field Manual Chapter 16

Riprap Toe Gradation

FWS	D100 =	3.20	inches
FWS	D50 =	2.28	inches
FWS	D30 =	2.05	inches

Appendix J
Scour Depth Calculations

F. X. Browne, Inc.

PA1731-01-001 Huntingdon Pike Dam Removal
Scour and Rip-Rap Calculations

Prepared by:	JMD	Date:	7/26/2006
Checked by:	JLW	Date:	8/16/2006

Toe depth calculation[1]				
Modified Laursen Equation				
$Ys/Ya=1.3(Wo/Ya)^{0.48}$				
Ys = scour depth				
Ya= depth of flow at structure	Highest water surface elevation from HEC-RAS model in wall section			
Wo = length of structure projected normal to flow				
XS	Ys/Ya	Wo (ft)	Ya (ft)	Ys (ft)
1	0.53	1	6.4	**3.41**
2	0.67	1	3.95	**2.66**
Average	0.60	1.00	5.18	**3.03**
[1] From EMRRP "Computing Scour ERDC TN-EMRRP-SR-05				

Appendix K
Stream Cross Sections and Plan Drawings