Aquetong Spring Park: Aquetong Creek Restoration Project
Solebury Township, Bucks County, PA

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Introduction

The Aquetong Creek restoration site is located in Solebury Township, Bucks County, PA, and encompasses the boundaries of the former Aquetong Lake. Aquetong Lake was a 15-acre impoundment formed in 1870 by the construction of an earthen dam on Aquetong Creek. The dam that defined Aquetong Lake was removed in 2015 as a controlled partial breach that drained the lake and re-exposed the lake bottom. The primary source of inflow to the headwater portion of Aquetong Creek that courses through the restoration site is Ingham Spring, an artesian spring formed at the contact of two geologic formations, with a sustained average flow rate of 2,000 gallons per minute (GPM) (F.X. Browne, Inc., 2004). There is some supplemental inflow to the creek in the form of storm water runoff discharged from the adjacent developed areas located to the north and south of the restoration site. The most significant supplemental source of inflow is an intermittent stream that enters the creek from the north. That stream runs under Route 202 and receives inflow from a sub-division located to the northeast of the restoration site. Aquetong Creek flows approximately 2.5 miles from Ingham Spring to join with the Delaware River in New Hope, PA.

A 2004 study funded by Bucks County Trout Unlimited concluded that the impoundment was negatively affecting downstream water quality, in particular water temperature (F.X. Browne, Inc., 2004). As noted above, in 2015, the dam was partially breached, and the lake drained, with the goal of reducing thermal impacts on the Aquetong Creek so as to support a high quality cold water fishery. The removal of the dam also negated the need for continued dam maintenance as well as the liability of environmental and property damage in the event of the dam's failure.

With the dam removed and the lake drained, a meandering channel formed through the exposed lakebed, connecting the upper and lower headwater sections of Aquetong Creek. Since the creek is primarily spring fed and the watershed is relatively small, over the years Aquetong Lake was subjected to a limited amount of sediment loading. Nonetheless, a layer of sediment had accumulated within the lake. Care was taken during the dam breach to manage this sediment and prevent its downstream transport. These efforts proved to be successful based on Princeton Hydro's assessment of the creek channel immediately down gradient of the former dam.

Despite the small watershed dominated by spring-fed flow, sufficient sediment had accumulated in the lake such that the meandering channel that re-formed following dam removal has initiated the process of channel incision or "downcutting." In general, downcutting is a term used in geomorphology to describe the active erosion of sediment from a stream channel bed that results in lowering the elevation of the channel bed and ultimately reduces the channel slope. Downcutting may also result in the widening of the stream channel, when banks reach a critical height and fail and erode. Downcutting and widening are two primary forms of channel adjustment that have been recognized in the channel evolution model (Schumm et al. 1981, Simon and Hupp 1986, Simon 1989) – a conceptual understanding of the sequence of events triggered by geomorphic instability. Downcutting and widening do not proceed indefinitely, but rather slow and nearly stop as the channel forms a balance, or equilibrium, between the flow of water and sediment that results in relatively stable channel depth, width, and slope. The rate of downcutting is partly governed by hydrologic and hydraulic factors, which affect the volume and rate of stream flow. It is also affected by the geologic properties of a site, the physical properties of the sediment in the creek channel, and the presence of stabilizing bank vegetation. It's important to note, that in geomorphic equilibrium, the channel is not static and immobile but rather the channel may adjust its dimensions, pattern, and slope incrementally around a normal condition. In this sense, geomorphic stability is dynamic, and "dynamic stability" is the natural condition that fosters the greatest ecological integrity.

At the Aquetong Creek site the severity of downcutting, creek channel instability, and erosion of the former lake bottom has thus far been minimal. As noted some of this is due to the consistent flow of the spring and the creek's relatively small contributing watershed. Some of this is also directly the result of the Township's reseeding and tree planting in the impounded area and the quick establishment of various pioneer plant species, which has helped revegetate the floodplain and stabilize the exposed lake sediments. However, certain sections of the creek channel are still unstable and underlain by additional erodible sediment. Further, the exposure of lake sediments following the dam breach allowed invasive species to colonize the formally unvegetated areas, negatively impacting the ecological functions and habitat qualities of newly exposed floodplain and upland areas.

The successful restoration of the former lake bed and the long-term management of the newly formed headwater reach of Aquetong Creek requires, as described below, the proper modifications to the creek channel and exposed lake bottom, as well as proper control of the invasive plant species present on the site. Doing so will foster the development of a creek that supports cold-water species, ecologically functioning riparian and upland areas, and a sustainable park setting.

The overall goals of this project were to document the existing ecologic and geomorphic conditions of the creek and contiguous former lake bed, and provide management and restoration guidance consistent with the following:

- A dynamically stable creek channel capable of passing various flow rates without being subject to erosion,
- A creek system capable of supporting a cold-water biological community,
- A floodplain/riparian area that complements and increases the ecological functions of the creek channel, and
- The creation of a passive recreational area and living classroom setting for the Township.

Methods

Wetland Delineation

The delineation of wetlands at the site by Princeton Hydro was based on the methods presented in the *U.S. Army Corps of Engineers Wetlands Delineation Manual of 1987* and the on-site wetland determination procedure presented in the *Interim Regional Supplement to the COE Wetland Delineation Manual: Eastern Mountains and Piedmont*. These methods involve a thorough investigation of three parameters, vegetation, soil and hydrology, to determine the presence of wetlands. Based on this approach, an area is defined as a wetland if it exhibits, under normal circumstances, all the following characteristics: (1) the land supports a dominance of hydrophytic vegetation, (2) the substrate is hydric soil, and (3) The soil/substrate is at least periodically saturated or inundated during a significant portion of the growing season. In addition to characterizing the ecological condition of the project site, the wetland delineation process is relevant to any permitting that may be required for future restoration and management plans.

A hydrophyte is any plant that has the ability to grow in water or on a substrate that is at least periodically deficient in oxygen as a result of excessive water content and depleted soil oxygen levels. The U.S. Fish and Wildlife Service (USFWS) has prepared a list of wetland and non-wetland plant species for the

Northeast Region of the U.S. (Region I) (Reed, 1988), which was used in surveying this site. Hydric soils are defined as very poorly drained, poorly drained, or somewhat poorly drained soils that have the seasonal high water table within 6 inches of the surface (Environmental Laboratory, 1987). These soils are typically predominantly gray and mottled immediately below the surface "A" horizon and have thick, dark colored surface layers.

Prior to the initiation of any field investigation, Princeton Hydro conducted a thorough review of available data such as the USFWS National Wetland Inventory (NWI) map, the Bucks County Soil Survey, site plans depicting the local topography, and any other resources that would facilitate the field delineation. For the field investigation, conducted November 21-22, 2016, Princeton Hydro established representative sampling points along the wetland line and at representative locations within each plant community assemblage on the site. At each sampling point, data regarding the vegetation, soil and hydrology of the area were collected, providing the information required to determine whether the area met the definition of a wetland. The site's wetland boundaries were marked with survey flagging, recorded using Princeton Hydro's survey-grade GPS, and overlaid on a GIS prepared orthorectified aerial photo of the site.

Biotic Assessment

A basic biotic assessment of the formerly impounded area was conducted in November 2016 to document the current ecology and hydrology of the site. GIS data sources were reviewed and relevant data were obtained to create maps documenting the restoration site's drainage area, soils, land use/land cover, and bedrock geology (Appendix A). These data were overlaid on a GIS prepared orthorectified aerial photo of the site. A recent (April 2016) topographic map of the restoration site prepared by C. Robert Wynn Associates was also utilized (Appendix A).

A more detailed stream survey was conducted in August 2017 to collect water quality, fish, and benthic invertebrate data. Sampling was conducted at five (5) stations located along Aquetong Creek (Appendix B). Four of the stations (Stations 2-5) were distributed down gradient of Ingham Spring but upgradient of the dam breach. The final station (Station 1) was located down-gradient of the breach, with this station serving as a "reference station" against which the upstream data was compared. The remaining four (4) stations were distributed somewhat uniformly along Aquetong Creek, but in a manner that enables evaluation of any impacts attributable to the Route 202 tributary.

Plant Community

The predominant vegetation communities present on the site were mapped. This assessment was based on the examination of multiple quadrats located along five (5) transects running from north to south across the site (Appendix C). Additionally, the entire site was walked to document the presence of invasive species. Emphasis was given to delineating the boundaries of large monotypic stands of invasive species, in particular *Phragmites australis* (Appendix C).

Habitat Conditions

Basic in-situ water quality and flow data were collected in November 2016 at a point below the Route 202 tributary confluence and in August 2017 at the 5 points described above, using a Price AA flow meter according to US Geological Survey protocol. These data included temperature, dissolved oxygen, pH, and conductivity. The creek's cross-sectional dimensions (width and average depth) and velocity were measured to compute the creek's flow (discharge) at each station using standardized USGS procedures for measuring creek discharge.

During the collection of the water quality and flow data, a basic visual stream assessment was conducted and the physical attributes of the creek at each sampling station were documented. This included the conditions of the creek's bed and bank, any evidence of scour or sedimentation, estimates of the amount of canopy cover, amount of riparian vegetation and riparian cover, water clarity, and any other relevant observational data that could affect the fish or benthic invertebrate communities. Stream substrate material was also surveyed throughout the creek reach and qualitatively evaluated (no samples were collected for quantitative laboratory processing).

Fish and Invertebrate Community

Sampling of the fishery was conducted in August 2017 and involved the use of a back pack electrofishing unit. Standardized passes of 100' reaches of the creek were conducted at each station. To maximize the return on the effort, a 50' bag seine was secured across the lower end of each sampled reach prior to electrofishing. The net helped capture any fish that may not have been collected by the dip netter working with the electrofisher. All collected fish were identified to species, measured (total length) and returned to the creek immediately following processing. The resulting fishery data was subjected to standard descriptive fishery statistical analyses (e.g. percent composition, dominance, catch per unit effort-CPUE, diversity, evenness, etc.).

Benthic invertebrate samples were collected at each station using a D-Net kick-sampler. All collected organisms were identified to lowest practical taxon and subjected to standard descriptive stream ecosystem statistical analyses (e.g. percent composition, dominance of EPT species, diversity, evenness, etc.). Benthic macroinvertebrate sampling in November 2016 was focused on the creek below the former dam, where extensive gravel and cobble riffles were present. At random locations along the creek, benthic macroinvertebrate samples were collected using a D-net. Also, random large stones were overturned and examined for colonization by various sedentary, clinging species. The D-net benthic macroinvertebrate samples were sorted in the field and identified to family. Emphasis was placed on establishing the presence of aquatic insect larvae of the orders Ephemeroptera, Plecoptera, and Trichoptera, which are recognized to be sensitive to water quality impairments. In August 2017, this sampling protocol was conducted at the 5 designated stations, not randomly along the creek reach.

Geomorphic Investigation

A geomorphic investigation of the impounded area was conducted to determine the distribution of accumulated sediments and identify instability in the current channel. The longitudinal profile of the main creek channel and the tributary that flows from the north under Route 202 were surveyed, with key features such as active head-cuts and stable grade controls identified. Four cross sections of the newly developed creek bed and floodplain were also surveyed along the main stem channel. At each survey point, the surface elevation and the depth of the underlying, unconsolidated sediments were recorded. Depth of underlying unconsolidated sediments was determined by manual probing with a graduated metal rod. Additionally, one cross section of the creek channel below the former dam was surveyed to document the bankfull channel dimensions and habitat features at a location which is assumed to be stable and in equilibrium with the typical flow in Aquetong Creek.

Results and Recommendations

Wetland Delineation

Overall, the majority of the formerly impounded area at Aquetong Creek was classified as having hydric soils due to its history of being underwater until 2015. However, this is not representative of current or future conditions, since the hydrology of the area has been significantly altered by the dam removal. Based on the post-dam removal hydrology and vegetation distribution of the site, the delineated wetland comprises a smaller portion of the hydric soils area.

Vegetation

As of November 2016, the formerly impounded basin possessed three wetland communities, including an emergent herbaceous wetland, and two distinct wet meadows (Appendix B). The emergent herbaceous wetland enclosed Aquetong Creek to the north and south, and was dominated by broadleaf cattail (*Typha latifolia*) and soft rush (*Juncus effusus*); woolgrass (*Scirpus cyperinus*), skunk cabbage (*Symplocarpus foetidus*), and narrowleaf cattail (*Typha angustifolia*) were also observed within this plant community. Two distinct wet meadows occurred upslope of the emergent wetland, north of Aquetong Creek. The wet meadow proximate to Aquetong Creek was characterized by a curly dock (*Rumex crispus*) monoculture that contained a dense copse of black willow (*Salix nigra*). The wet meadow distal to Aquetong Creek was dominated by rough barnyardgrass (*Echinochloa muricata*) and eastern cottonwood (*Populus deltoides*) saplings. Other species observed within this community included: sensitive fern (*Onoclea sensibilis*), Japanese stiltgrass (*Microstegium vimineum*), and path rush (*Juncus tenuis*).

Soils

Soil borings collected from the wetlands onsite exhibited hydric characteristics, including low chroma (<2). The soils within the wetland consisted of: (0”-6”) gray 7.5YR 5/1 silty clay loam with oxidized rhizospheres, (6”-18”) dark gray 7.5YR 4/1 silty clay loam with red 2.5YR 4/6 redoximorphic features, and the soil (>18”) was gleyed. These features indicate saturated soil conditions that have affected the chemical and physical environment of the soil.

Hydrology

The site contains headwaters of Aquetong Creek, which originates from Aquetong Spring on the eastern portion of the site and flows from the west to east. The wetlands delineated on site occurred in the areas that were formerly inundated by the now-removed Aquetong Dam. As a result of the previous inundation, numerous wetland hydrology indicators were observed at the sampling locations. These indicators included sediment deposits, surface soil cracks, oxidized rhizospheres, a marked drop in topographic elevation, and the presence of hydric soils and obligate plant species.

Biotic Assessment

Plant Community

Based on five transects across the former impoundment area, the site exhibited a pattern of emergent herbaceous vegetation at lower elevations near the creek, transitioning to *Rumex* spp., *Phragmites australis*, and woody species in the upland areas (Appendix C).

Habitat Conditions

The creek at the time of our investigation in December 2016 had a measured flow of 5 cubic feet per second (ft^3/s), which is equivalent to 2,200 gallons per minute (gpm). In August 2017, flow measured the equivalent of 2,135 gpm (Appendix E, Table 1). These flow measurements are consistent with previously reported flows from Ingham Spring (F.X. Browne, Inc., 2004). During our study of the creek, it was visually apparent that the flow in the tributary that enters Aquetong Creek from the north under Route 202 was very low as compared to that measured in Aquetong Creek. Estimated stream flow data for the tributary stream was also obtained from the USGS StreamStats program, which uses regressions of regional hydrologic data to calculate flow characteristics for ungaged streams, (Appendix D). However, these regression equations are not designed for watersheds of this small size, so these values are reported here to provide context but should not be considered conclusive. Daily mean discharge is estimated to be 0.29 ft^3/s; the 2-year peak flow is estimated to be 18.1 ft^3/s. The flow of the Route 202 tributary was measured in August 2017 at 0.046 ft^3/s, or approximately 20.8 gpm. Thus, while Aquetong Creek's flow is primarily affected by the discharge of water from Ingham Spring, the tributary's flow is dictated by precipitation and runoff, and as such, Aquetong Creek's flow should be relatively stable while the tributary's flow will be more variable and dependent on the magnitude and intensity of storm events. Additionally, the tributary's flow is also affected by the large detention basin that is part of the Silvertail Lane development and the pond located immediately north of Route 202. Both may mitigate peak flows and control the rate of discharge to the tributary.

Fish and Invertebrate community

Tables 2 of Appendix E summarizes the fish community data. The highest abundance and diversity of fish occurred at the downgradient station closer to the area of the dam breach (Station 2); two brook trout, among other fish, were sampled at Station 2 on a second pass of collecting. Otherwise, American eels (*Anguilla rostrata*) dominated most of the areas where fish were found. No fish were collected within the section of Aquetong Creek located within the former impoundment or in the Route 202 tributary. Salamanders were observed at most sites.

The trout collected measured 210mm and 230mm with approximate extrapolated weights of 0.23 and 0.30 lbs, respectively (PA Fish an Boat Commission). Based on areas sampled, there is an average relative abundance of 17 fish per acre with a biomass of approximately 4.5 lbs per acre. Based on the data collected during our survey, the upper reach of Aquetong Creek cannot presently be classified as a Class A Brook Trout stream by PA DEP criteria (total wild brook trout biomass of at least 26.7 lbs/acre, PADEP 2014). However, our data suggest that conditions exist which are supportive of brook trout.

Table 3 of Appendix E summarizes the benthic invertebrate community data. Amphipods and mayflies were the dominant invertebrate species at most sites, with flies and true bugs in high abundance in the Route 202 tributary. Individuals from the orders Ephemeroptera (mayflies), Trichoptera (caddisflies), and Plecoptera (stoneflies) composed approximately 25-30% of the population collected at the two stations located at and below the dam breach (Stations 1 and 2, respectively) and decreased upstream. The presence of these three orders of aquatic insects (EPT spp.) is indicative of good water quality, as they are sensitive to declines in stream health.

The D-net samples did not include aquatic insect species typically indicative of poor stream health. The samples also contained Tipulidae (crane flies), amphipods, isopods, mollusks (*Corbicula*), and Planaria (flatworms). The occurrence of *Corbicula* is of concern as it is a non-native, invasive clam. It is common in the Delaware River and other waterways throughout Pennsylvania. It's occurrence in the creek samples is likely a result of it having been present in the lake.

In contrast to the reaches at the furthest ends of the sampled area, the reach of Aquetong Creek running through the former impounded area generally had poor macroinvertebrate habitat, with the bed of the creek consisting primarily of fine formerly impounded sediment and lacking coarser-grained gravel and cobble. However, given the high quality of macroinvertebrates in the creek below the dam and the overall high water quality of Aquetong Creek, it is expected that as the channel adjusts and equilibrates to a more dynamically stable form with improved habitat features like riffles, pools, and runs, with gravel and cobble substrate, the project reach will support a healthy biotic community. As of August 2017, the highest species richness and total relative abundance of fish (including two trout) were found in the project reach just upstream of the dam breach, supporting this expectation.

Overall, the studied segment of Aquetong Creek exhibited excellent ecological health and was characterized by conditions supportive of a trout population. The cool, oxygen-rich, spring fed water exhibits natural riffles and glides as preferable trout habitat. There is plentiful detritus, decaying vegetative matter (leaves branches etc.), invertebrates, and vertebrates (salamanders) to support a healthy food web. Invertebrate species that are typically indicative of poor stream health were not found. Macroinvertebrates belonging to the sensitive orders Ephemeroptera (mayflies), Trichoptera (caddisflies), and Plecoptera (stoneflies) were present, indicating good water quality. Tipulidae (crane flies), amphipods, isopods, Mollusca (*Corbicula*), and Planaria (flatworms) were also observed.

In order to maintain and eventually optimize trout habitat and support a potential trout fishery in the future, Princeton Hydro recommended that Solebury Township implement future creek restoration and enhancement measures that support stable geomorphic processes and limit the establishment of invasive ripairan and floodplain vegetation. Stabilizing the banks and minimizing the amount of down-cutting will facilitate the immediate persistence and future expansion of desirable riffle and run habitat. As previously recommended by Princeton Hydro, the selective excavation of the lower creek channel to the bottom and expansion of its width will help to achieve greater stability. The previously proposed floodplain bench will allow flood flows to spread out across a wider area of the adjacent developing riparian area, further stabilizing the banks. Further, Installation of large wood features within the restored creek channel will further provide stability to the restored channel. In-creek large wood creates varied hydraulic conditions, diversifies creek bed substrate types, and provides fish cover, resting, and feeding habitat.

Princeton Hydro, LLC also recommended restricting angling in this creek, as the trout population is limited and the removal of any individuals will substantially decrease the population available for spawning and recruitment, as well as decreasing genetic diversity.

Invasive Species Management

A number of invasive plant species have already colonized the former lake bed and adjacent riparian areas since it was exposed in 2015. The species of concern include Japanese honeysuckle, multiflora rose, reed canary grass, mugwort, Japanese barberry, Canada thistle and common reed (Phragmites *australis*). Dock (*Rumex* sp.), a common upland weed, has become widely established throughout a large portion of the former lake bed. It is recommended that a more accurate identification of this plant be conducted in the spring once more distinguishable plant structures are evident. There are also some patches of cattail (*Typha*) that have become established, generally near the creek. Although some consider cattail an invasive species, it has positive habitat properties. Thus, although over time its growth and distribution should be monitored, at this time the existing stands of *Typha* do not need to be controlled. Reed canary grass, Canada thistle and mugwort will be an ongoing issue. Although annuals, they thrive in the open areas of the site, especially and along the edges of the mowed paths. Controlling Canada thistle and mugwort will therefore be difficult and likely unsuccessful given the pervasiveness and wide spread distribution of these species. Conversely, the reed canary grass, most of which is growing in the wetter areas near the creek, should be targeted for treatment with an herbicide before it dominates the newly developing riparian areas. Alternatively, if additional earthwork is planned in the riparian areas as recommended below, treatment of these areas can be deferred instead for re-grading and active re-planting. In addition, to control Japanese honeysuckle, Japanese barberry, multiflora rose, and large areas impacted by mugwort, the entire site should be walked and selectively sprayed in the spring with an herbicide using backpack application techniques. Care will need to be taken to control the drift of the herbicide so as not to impact other desirable plants occurring at the site. Details of the proposed herbicide treatment program are provided below.

The invasive plant of greatest concern is *Phragmites australis* (*Phragmites*). *Phragmites* has colonized five distinct areas within the boundaries of the former lake bed and adjacent riparian and upland areas, and is denoted in red in the Vegetation Communities map (Appendix B). During the November 2016 inspection of the site the general boundaries of the major *Phragmites* stands were delineated using a handheld GPS. The majority of the *Phragmites* is located near the head of the creek close to the spring source, directly bordering on the creek. Other major areas of growth occur in the northeast corner and in the far western end of the site. These stands may be hydrologically supported by upland seeps.

It was recommended that all *Phragmites* should be systematically cut and treated with herbicide until complete eradication is achieved. Given that *Phragmites* is a very difficult plant to eradicate, it is recommended that the Township implement a five (5)-year invasive plant management plan. Most annual and secondary growth in *Phragmites* stands sprouts directly from the plant's extensive rhizome system, requiring an aggressive and diligent control program. Uptake and translocation of the herbicide throughout the entire plant is crucial to its successful management. This is best accomplished by treating the actively growing plants with a systematic herbicide and a seasonally-timed mowing/cutting regiment, which entails cutting and harvesting the *Phragmites* twice annually. Cutting the *Phragmites* in advance of the seasonal treatments prevents the dead stalks from blocking the sprayed herbicide and exposes the plant's meristem, further enabling the translocation of the herbicide into the extensive rhizome system. A similar approach can be used to control the areas impacted by Japanese knotweed, another plant with an aggressive and extensive rhizome system.

Each year the vigor of the remaining *Phragmites* and the other targeted invasive plants should be documented to evaluate the effectiveness of the previous year's management efforts. Tracking the site's invasive species will help guide the Township's long-term invasive species management decisions, with the goal of achieving complete eradication of the *Phragmites* and control of the other invasives. The program must result in less invasive species growth, the prevention of the spread of invasives into additional areas, and decreased competition between the invasive species and the naturally occurring and introduced desirable plant communities.

Aquapro (glyphosate), Habitat (Imazapyr) and Renovate3 (triclopyr) were the herbicides assessed for use in the control the invasive plants present in the former lake bed as well as adjacent to both riparian and upland areas.

After concerns were raised about the use of glyphosate products, it was agreed that Habitat (imazapyr) was a more agreeable alternative as it would provide better, longer *Phragmites* control. It was acknowledged that although Imazapyr (Habitat) could remain partially active within the soil (thus affecting re-planting and re-colonization efforts) for up to a year, it would be rather than the glyphosate since it would require less repeat herbicide applications in subsequent years.

Princeton Hydro licensed applicators treated two large stands of *Phragmites* with Habitat on September 22, 2017. One of the stands is located directly east of Ingham Springs and south of the historic building. The larger of the two stands is located due east of the historic building (Appendix C). The two treated stands were inspected by Princeton Hydro and Solebury personnel on November 9, 2017. The Habitat treated stands were found to be largely dead or dying. It was recommended that both treated stands of *Phragmites* be cut and cleared after the first frost. Given the aggressive nature of *Phragmites* it is more than likely that both stands will need to be re-treated next year (2018).

Due to concerns raised in general regarding the overall use of standard herbicides to control the site's invasive species, over the spring and summer of 2017 the Solebury Township Public Works Department and volunteers with the Environmental Commission implemented alternative control techniques for other stands of *Phragmites.* The goal of these efforts was to evaluate the efficacy of these other products or control options with respect to the long-term management of invasive plant species. A section of the stand of *Phragmites* to the west of the road access across from Silver Tail Lane was treated with Weed Zap, an organic treatment composed of clove oil and cinnamon. Another small stand was mowed and covered with a plastic barrier weighted down with cinders. This treatment area has not been formally evaluated, but signs of regrowth around the perimeter of the barrier were observed during the November 9, 2017 site walk.

The control of *Phragmites*, knotweed and reed canary grass will likely be an ongoing issue of concern for the Township. We thus strongly recommend that a long-term wetland and riparian invasive species management plan be developed for the site. The plan should include in combination of standard and alternative herbicides, the use of physical and biological control options. The control plan needs to include a planting plan to replace the invasive species controlled in given area. The Township can review the plan annually and modify it as necessary with the ultimate goal being the long-term control of invasive species and their replacement with beneficial native species, especially those that can increase the ecological services and functions of the riparian corridor.

Finally, there will be the need to eventually control the poplar, cottonwood and willow that have colonized the lake bed. While all three trees help to stabilize the site, the poplar and cottonwood are less desirable long-term species. A plan will need to be developed to selectively and sequentially remove some of the poplar and cottonwoods. They can then be replaced with trees having greater ecological value. It has been determined that willows need not be controlled or reduced at this time.

Geomorphic Investigation and Design Concept

Since the removal of Aquetong Lake Dam as discussed above, Aquetong Creek has re-formed and begun downcutting through the formerly impounded sediments, exhibiting channel instability as it erodes sediment from the creek bed and banks. The focus of the geomorphic analysis was to assess channel stability, and to determine the depth and distribution of formerly impounded sediments and the potential for ongoing geomorphic adjustment and instability. In addition, a reference reach was identified downstream of the dam which provided an estimate for equilibrium channel cross-sectional dimensions for the upstream reach of Aquetong Creek.

Substantial accumulations of formerly impounded sediment remain in the mainstem of Aquetong Creek in the lower reach of the former lake. The first evidence of this occurs at a headcut approximately 3 feet in height, approximately 100 feet upstream of the former dam. Extending an additional 700 linear feet upstream, typical depths of 1.5-2 feet of erodible sediment remain below the existing channel invert. The channel cross-section in this reach is incised and entrenched, particularly relative to the reference reach identified downstream of the dam (Figure 1). In contrast, the upper reach of Aquetong Creek, approximately 1,000 feet upstream of the dam, and approximately 100 feet upstream of the unnamed tributary, contains lesser accumulations of erodible sediment with an average depth of 0.7 feet. Reduced sediment depth in this reach is consistent with this portion of the creek being a nearly constant inflow thus precluding sediment deposition, that is in addition, primarily spring-fed and thus carrying minimal sediment. As is typical, the greatest proportion of finer sediment particles have deposited in the lower portion of the lake due to the longer settling times.

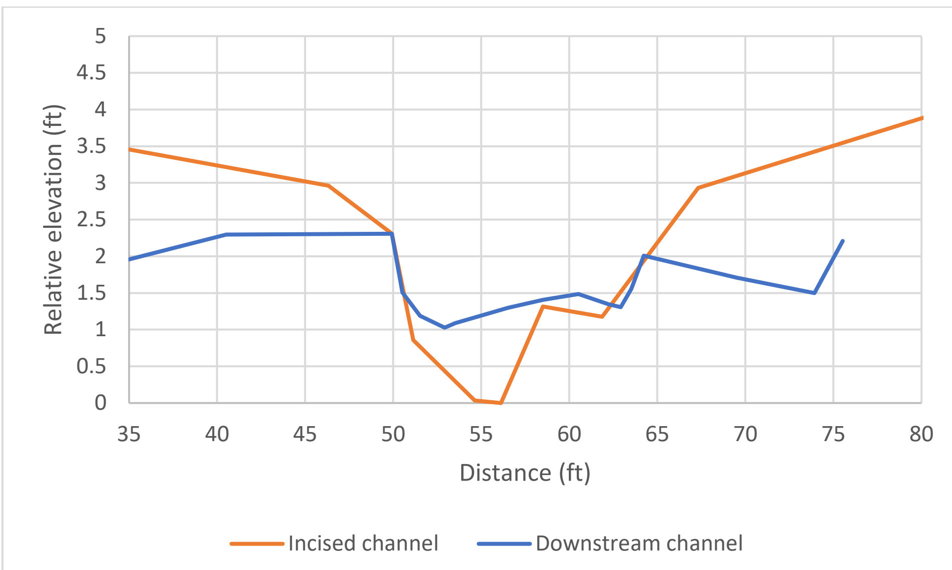

Figure 1. Comparison between the channel cross-section downstream of the dam and the incised channel upstream of the dam.

Substantial accumulations of formerly impounded sediment also remain in the unnamed tributary to Aquetong Creek draining from Route 202. Several headcuts 1-2 feet in height exist upstream of the confluence with Aquetong Creek. The sediment deposits along the tributary channel averages 2 feet deep, with as much as 5 feet of deposited sediment in some locations.

Downcutting will continue as the existing headcuts migrate gradually upstream, producing channels that are further incised and disconnected from the floodpain and adjacent riparian area. Channel instability and the adjustment process will continue for years, potentially a decade or more, before a dynamically stable dimension, pattern, and profile are attained and optimal habitat conditions are created. Further, sediment erosion may contribute to water quality impairments, associated with turbidity and nutrients, in the downstream reaches.

This spatial distribution in sediment thickness throughout the former impoundment leads to a geomorphic creek restoration approach that focuses on the Route 202 tributary channel and lower main stem of Aquetong Creek, and the adjacent floodplain/riparian area. We propose the selective excavation of the lower creek channel to the bottom. Additionally, we propose the channel to be expanded to a stable width and a floodplain bench created adjacent to the new channel. This bench will allow flood flows to spread out across a wider area of the adjacent developing riparian area. This proposed excavation targets the unconsolidated sediment that over the short and medium term would otherwise be eroded and transported to downstream reaches. Complete conceptual restoration plans for Aquetong Spring Park are in Appendix F.

Main stem channel excavation dimensions will be modeled from the dimensions of the stable channel below the dam, with a width of approximately 14.5 feet and a depth of 1 foot. To avoid entrenchment, the excavated floodplain bench shall be approximately two times the channel width, with a stable 3H:1V slope to meet the surrounding grade. Approximately 770 feet of the channel will be targeted for restoration. We propose a similar approach to the tributary channel alterations, with the channel excavated for a length of approximately 450 feet to be approximately 0.6 feet deep and 7 feet wide with a floodplain bench 14 feet wide. These dimensions are based on published hydraulic geometry curves applicable to the site and developed for the encompassing physiographic regions of the northeast (Bent 2006; Johnson and Fecko 2008). It appears based on preliminary estimates that the proposed excavation may generate an estimated 6,000 cubic yards of earthen material; however, a more detailed cut/fill analysis will be required during the final design to confirm this estimate and to ensure a balance between the planned excavation and the space available for onsite placement of this excavated material. This is a small volume of material relative to the total volume of formerly impounded sediment, that can be re-distributed on- site thus avoiding the cost for its off-site transportation. There are multiple options for placing sediment onsite, such as spreading it thinly across the hillslope area of the former lake bed, creating elevated landscape features for viewpoints (e.g. knolls), circular berms for outdoor classroom seating, or filling the former raceway located downstream of the dam.

To further enhance the ecological function of the creek, we also recommend the installation of large wood features within the restored creek channel. In addition to providing stability to the restored channel, in-stream large wood creates varied hydraulic conditions, diversifies creek bed substrate types, and provides fish cover, resting, and feeding habitat. Existing onsite large wood currently located in the former emergency spillway raceway can be re-located to the channel. Depending on the availability of large wood, in-stream features will be prioritized, but surplus wood may be used for further channel bank and floodplain stabilization and habitat enhancement/creation. Sediment excavation within the channel may re-expose former creek bed substrates; however, if underlying materials are unsuitable (i.e. lacking in gravels and cobbles), additional gravel/cobble graded stone may be imported as additional substrate to supplement selected riffle and run features and further enhance the habitat quality of the restored reach.

Passive Recreation

The long-range plans for the site include trail systems, interpretive signage and perhaps even living class-rooms that can be utilized by residents and visitors. The layout of trails, vistas, informational kiosks, etc. will need to be finalized after the former lake bottom stabilizes and final geomorphologic changes are made to the stream channel.

Long Term Monitoring

In order to properly maintain the ecological health of the restored area, continued monitoring Is essential. Princeton Hydro, LLC recommends taking continuous *in situ* water quality data with sondes placed in the creek in at least three stations:

- Station 5 to monitor close to the spring
- Station 4 to monitor water entering the system from the Route 202 tributary
- Station 2 to monitor the stream below the confluence of channels and at the breach

Data from these sites will give reliable and comparable information from crucial points of the system and its associated watershed and will demonstrate and any changes in rates of inflow and discharge resulting from the restoration work.

In addition, seasonal (spring, summer, fall) vegetation surveys from at least 6 areas including undisturbed habitat and restored wetlands, riparian buffer, and treated invasive patches should be conducted to ascertain positive impacts of invasive plant control and riparian buffer plantings. The need and extent of further invasive plant treatment can then be assessed based on monitoring results.

Finally, yearly biotic assessments should be conducted following the protocol as described for the August 2017 bioassessment. Monitoring for biotic data is recommended to be collected from at least each of the three aforementioned in situ water quality stations (Stations 2, 4, and 5).

References

Bent, G.C., 2006, Equations for estimating bankfull channel geometry and discharge for streams in the northeastern United States [abs.]: Proceedings of the Eighth Interagency Sedimentation Conference, Reno, Nevada, April 2–6, 2006, p. 1026, accessed April 16, 2013, http://pubs.usgs.gov/misc_reports/FISC_1947-2006/pdf/1st-7thFISCs-CD/8thFISC/Poster_Bent_AbstractOnly.pdf.

Environmental Laboratory, 1987. U.S. Army Corps of Engineers Wetlands Delineation Manual. Technical Report Y-87-1, U.S. Army Engineer Waterways Experiment Station, Vicksburg, Miss.

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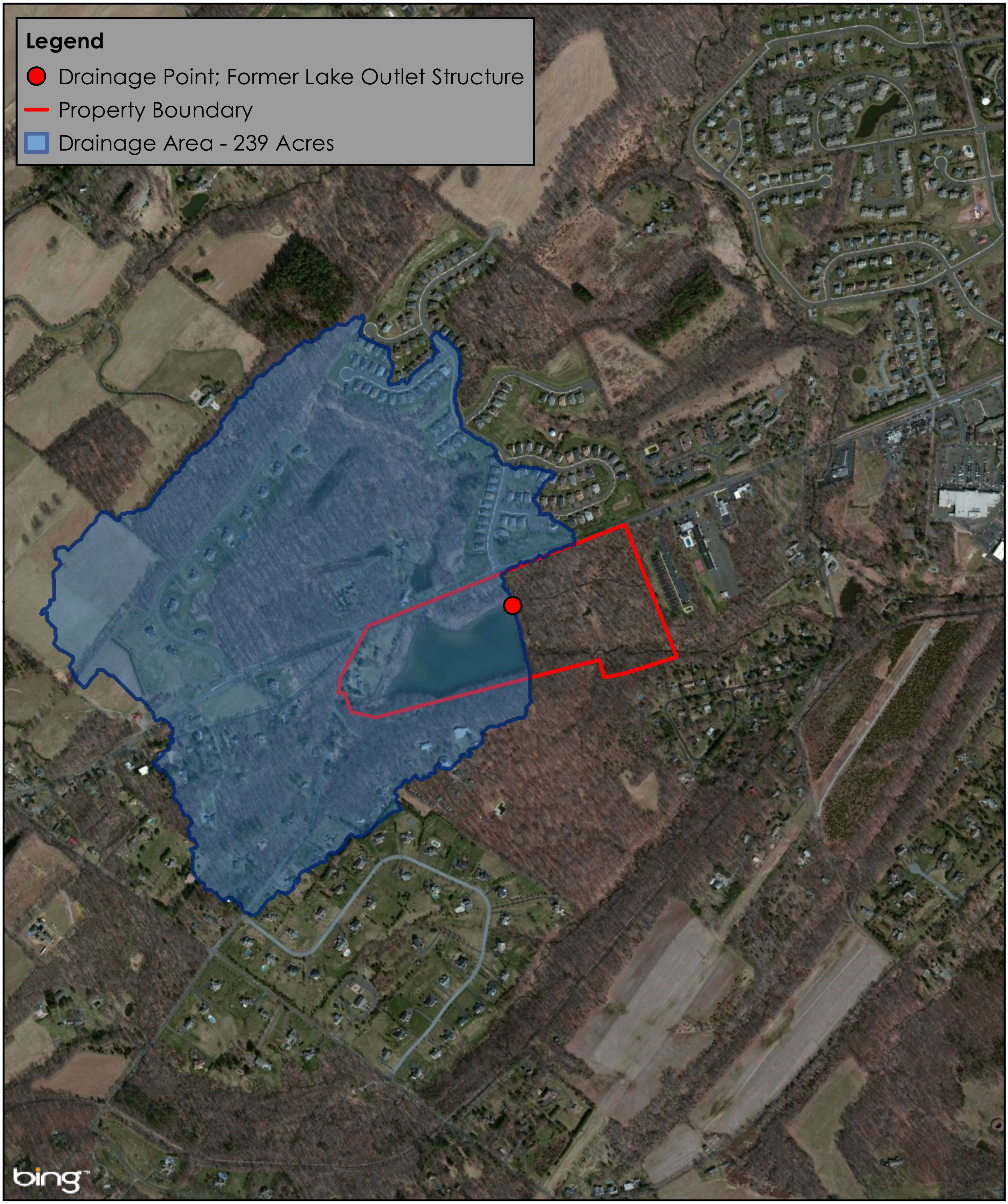
Appendix A: GIS Site Data



File: P:\0388\Projects\0388003\GIS\MXD\DA.mxd, 2/3/2017, Drawn by thopper. Copyright Princeton Hydro, LLC.

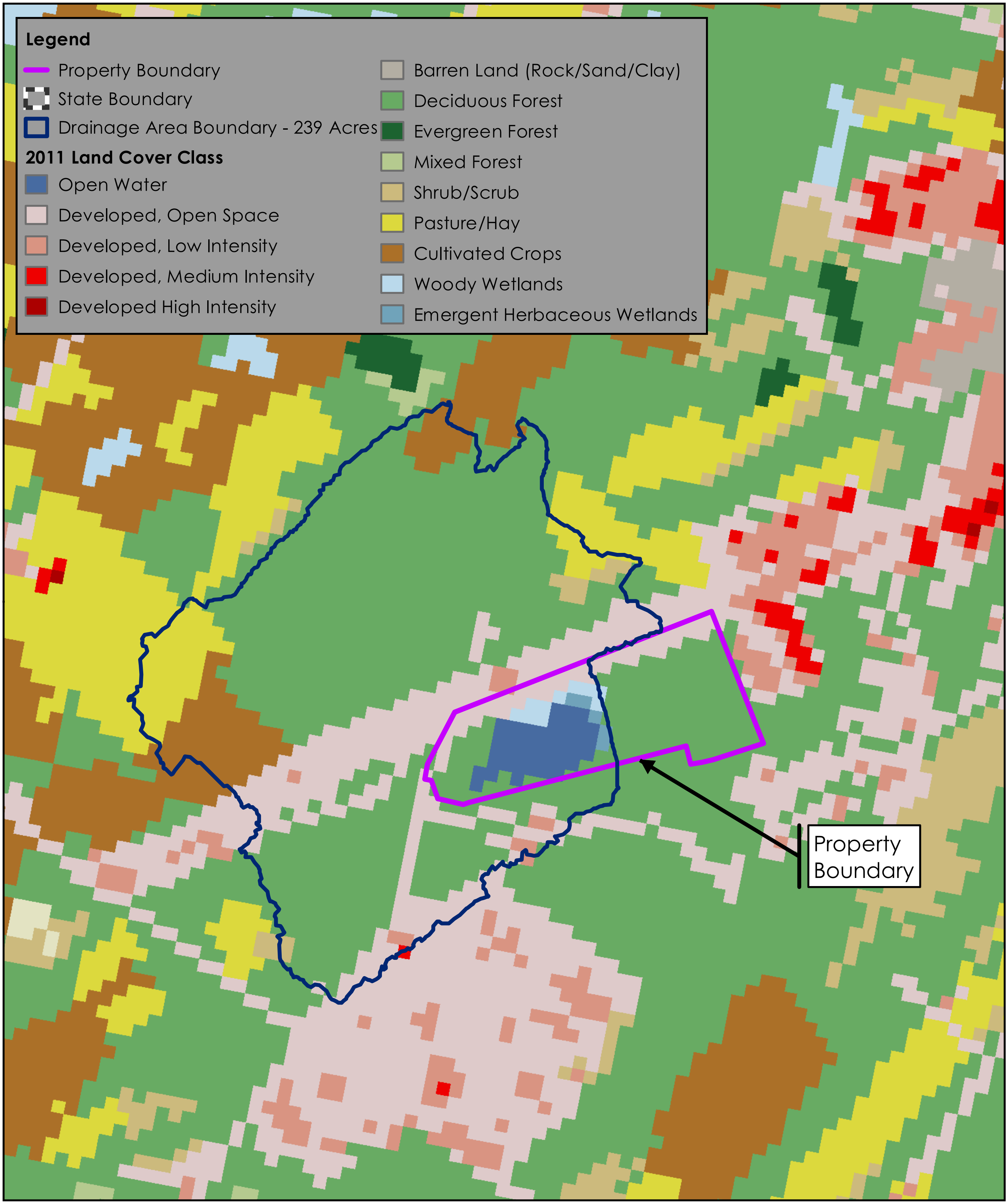
DRAINAGE AREA MAP

AQUETONG SPRING PARK
SOLEBURY TOWNSHIP
BUCKS COUNTY, PENNSYLVANIA

PRINCETON HYDRO, LLC.
1108 OLD YORK ROAD
P.O. BOX 720
RINGOES, NJ 08551
*with offices in NJ, PA and CT

NOTES:
1. Drainage area delineated by Princeton Hydro, LLC using 2008 LIDAR data obtained from the Pennsylvania Spatial Data Access (PASDA).
2. 2011 aerial imagery obtained through ArcGIS Online Bing Maps (C) 2016 Microsoft Corporation and its data suppliers

Map Projection: NAD 1983 StatePlane Pennsylvania South FIPS 3702 Feet



2011 LAND COVER MAP

AQUETONG SPRING PARK
SOLEBURY TOWNSHIP
BUCKS COUNTY, PENNSYLVANIA

pH
PRINCETON HYDRO, LLC.
1108 OLD YORK ROAD
P.O. BOX 720
RINGOES, NJ 08551
*with offices in NJ, PA and CT

NOTES:
1. 2011 land cover obtained from the Multi-Resolution Land Characteristics (MRLC) consortium's, National Land Cover Database (NLCD).

0 500 1,000 Feet

Map Projection: NAD 1983 StatePlane Pennsylvania South FIPS 3702 Feet

File: P:\0388\Projects\0388003\GIS\MXD\SSURGO.mxd, 2/3/2017, Drawn by thopper, Copyright Princeton Hydro, LLC.

SSURGO SOILS MAP

AQUETONG SPRING PARK
SOLEBURY TOWNSHIP
BUCKS COUNTY, PENNSYLVANIA

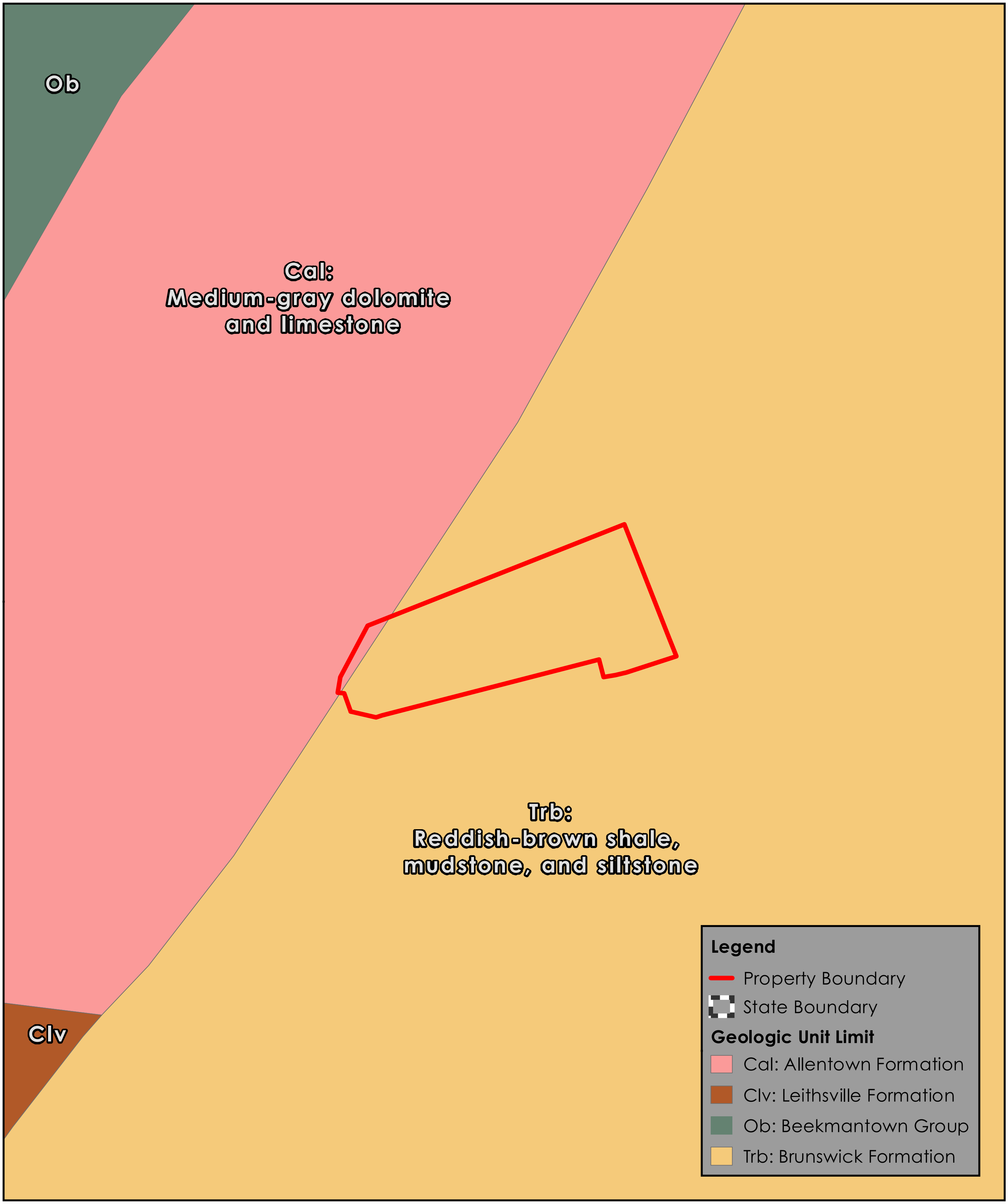
pH

PRINCETON HYDRO, LLC.
1108 OLD YORK ROAD
P.O. BOX 720
RINGOES, NJ 08551
*with offices in NJ, PA and CT

NOTES:
1. SSURGO Soils obtained from NRCS, USDA, Soil Survey Geographic (SSURGO) Database for Bucks County, Pennsylvania.
2. 2011 aerial imagery obtained through ArcGIS Online Bing Maps (C) 2016 Microsoft Corporation and its data suppliers.

0 250 500 Feet

Map Projection: NAD 1983 StatePlane Pennsylvania South FIPS 3702 Feet



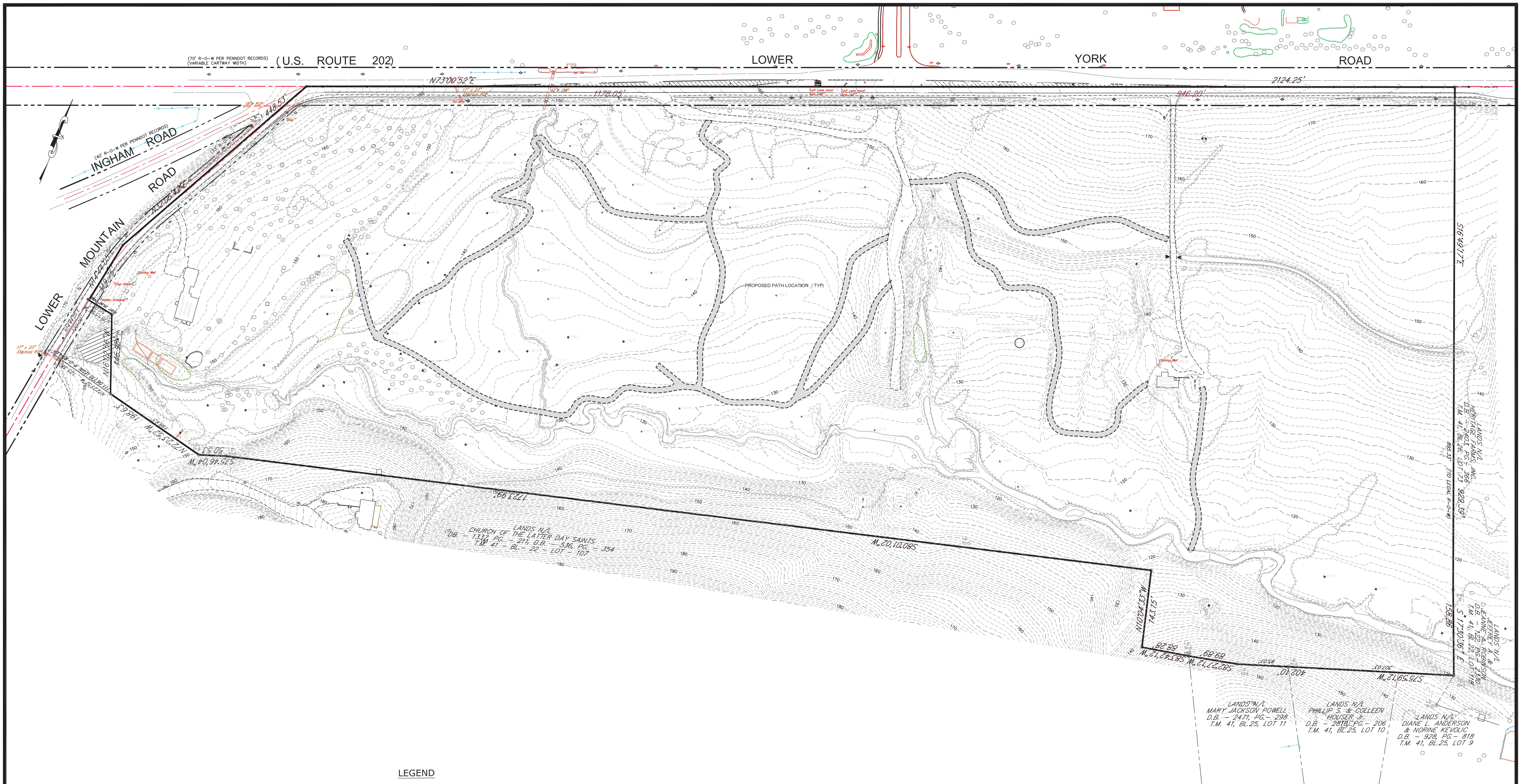
BEDROCK GEOLOGY MAP

AQUETONG SPRING PARK
SOLEBURY TOWNSHIP
BUCKS COUNTY, PENNSYLVANIA

PRINCETON HYDRO, LLC.
1108 OLD YORK ROAD
P.O. BOX 720
RINGOES, NJ 08551
*with offices in NJ, PA and CT

NOTES:
1. Bedrock geology obtained from the Pennsylvania Department of Conservation and Natural Resources (PA DCNR), Geological Survey.
2. State boundary obtained from the Pennsylvania Spatial Data Access (PASDA).

Map Projection: NAD 1983 StatePlane Pennsylvania South FIPS 3702 Feet



LEGEND

- LEGAL RIGHT-OF-WAY
- PHYSICAL CENTERLINE
- PROPERTY BOUNDARY

EXISTING FEATURES

- EDGE OF PAVEMENT
- EDGE OF WATER
- CONTOUR-MINOR INTERVAL
- 130 CONTOUR-MAJOR INTERVAL
- × 138.5 SPOT ELEVATION
- UTILITY POLE
- SIGN
- LIGHT
- EDGE OF WOODS
- TREES STANDING ALONE
- PROPOSED PATH LOCATION

PENNSYLVANIA ONE CALL SYSTEM, INC.
925 Irwin Run Road
West Mifflin, Pennsylvania
15122 - 1078

PENNSYLVANIA ONE CALL SYSTEM, INC. 1-800-242-1776 STOP-CALL BEFORE YOU DIG!

BEFORE YOU DIG ANYWHERE IN PENNSYLVANIA! CALL 1-800-242-1776

NON-MEMBERS MUST BE CONTACTED DIRECTLY

PA LAW REQUIRES THREE WORKING DAYS NOTICE TO UTILITIES BEFORE YOU EXCAVATE, DRILL, BLAST OR DEMOLISH

PENNSYLVANIA ONE-CALL NOTATION:
LOCATION OF ALL EXISTING UTILITIES SHOWN ON THIS PLAN HAVE BEEN DEVELOPED FROM FIELD LOCATIONS OF VISIBLE ABOVE GROUND STRUCTURES AND INFORMATION PROVIDED BY UTILITY COMPANIES/AUTHORITES THROUGH THE ONE-CALL PROCESS. ALL LOCATIONS MUST BE CONSIDERED APPROXIMATE. COMPLETENESS OR ACCURACY OF LOCATIONS OR DEPTHS OF ALL STRUCTURES IS NOT GUARANTEED. CONTRACTORS UTILIZING THIS PLAN MUST VERIFY ALL LOCATIONS AND DEPTHS OF UNDERGROUND UTILITIES AND FACILITIES PRIOR TO COMMENCEMENT OF CONSTRUCTION WORK OR DEMOLITION. PURSUANT TO ACT 187, PA HOUSE BILL 2627, PRIOR TO THE START OF ANY EXCAVATION OR DEMOLITION WORK, THE CONTRACTOR MUST NOTIFY ALL AFFECTED UTILITY COMPANIES THROUGH THE PENNSYLVANIA ONE-CALL SYSTEM (1-800-242-1776) A MINIMUM OF THREE (3) WORKING DAYS PRIOR TO COMMENCEMENT OF ANY CONSTRUCTION/EXCAVATION. THE CONTRACTOR MUST VERIFY THE LOCATION AND DEPTH OF ALL UTILITIES PRIOR TO THE START OF ANY CONSTRUCTION.

PLAN REFERENCES:

1. '2-LOT MAJOR SUBDIVISION PLAN INGHAM SPRINGS' PREPARED BY C. ROBERT WYNN ASSOCIATES, INC. DATED DECEMBER 4, 2008, LATEST REVISION 5-11-09
2. 'CONSERVATION EASEMENT PLAN - LOTS 1 & 2 INGHAM SPRINGS' PREPARED BY C. ROBERT WYNN ASSOCIATES, INC. DATED AUGUST 18, 2009.
3. THIS PLAN DOES NOT IDENTIFY EASEMENTS OR RESERVED AREAS.
4. 'TOPOGRAPHIC MAPPING INGHAM SPRINGS' PREPARED ROBINSON PHOTOGRAMMETRIC MAPPING DATED 04/11/2016, FLIGHT DATE 03/07/2016, PENNSYLVANIA STATE PLANE COORDINATE SYSTEM - PA SOUTH ZONE, VERTICAL DATUM NAVD88.
5. APPROXIMATE PATH LOCATION PER FIELD DELINEATION COMPLETED ON 11/4/2016 BY DENNIS M. LITZENBERGER, PLS.

80 40 0 80 160
SCALE: 1" = 80'

NO.	DATE	REVISIONS

PATH LOCATION SKETCH PLAN

AQUETONG SPRING PARK

SOLEBURY TOWNSHIP, BUCKS COUNTY, PENNSYLVANIA

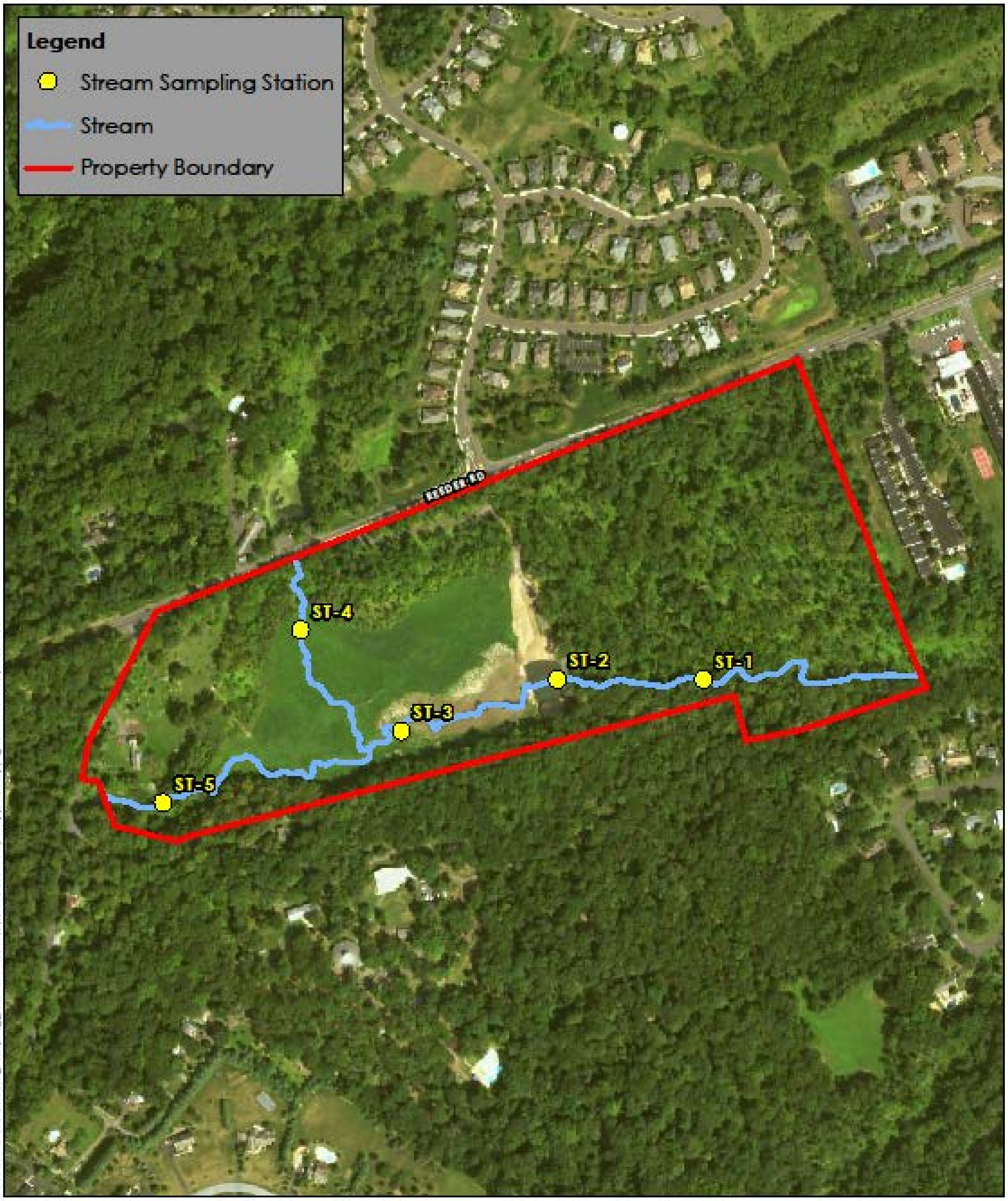
C. ROBERT WYNN ASSOCIATES, INC.
MUNICIPAL ENGINEERING SERVICES
211 W. Broad Street, Quakertown, PA 18951 Phone 215-536-7336 Fax 215-536-5361

DRAWING NO. 1 OF 1

DRAWN BY DAD	CKD BY CJG	DATE: 11/9/2016	SCALE 1" = 80'	JOB NO.: 83-082

G:\MUNICIPAL\SOLEBURY\83- File Numbers\83-082 Aquetong Spring Park\acad\AQUETONGSPRINGPARK - Trail Sketch with ortho.dwg, 11/9/2016 1:18:09 PM, Adobe PDF

Appendix B: Map of Fish and Macrobenthic Invertebrate Survey Sites



STREAM SAMPLING STATION MAP

AQUETONG SPRING PARK
SOLEBURY TOWNSHIP
BUCKS COUNTY, PENNSYLVANIA

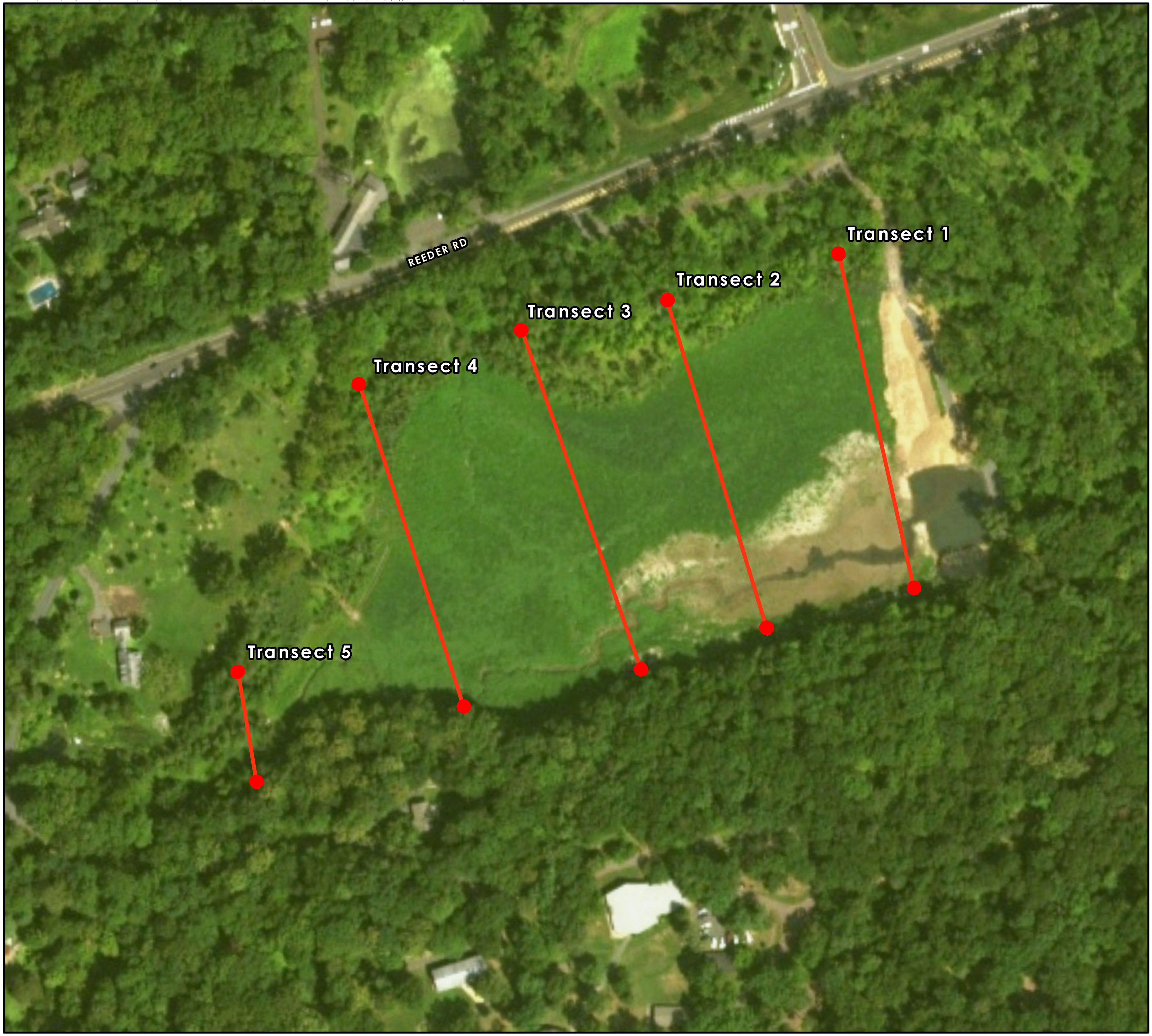
PRINCETON HYDRO, LLC.
1108 OLD YORK ROAD
P.O. BOX 720
RINGOES, NJ 08551
*with offices in NJ, PA and CT

NOTES:
1. Stream sampling station locations are approximate.
2. 2015 orthoimagery obtained from the United States Department of Agriculture's (USDA), National Agriculture Imagery Program (NAIP).

0 200 400 Feet

Map Projection: NAD 1983 StatePlane Pennsylvania South FIPS 3702 Feet

Appendix C: Vegetation Maps



PENNSYLVANIA COUNTY MAP

PRINCETON HYDRO, LLC.
1108 OLD YORK ROAD
P.O. BOX 720
RINGOES, NJ 08551
*with offices in NJ, PA and CT

1 inch = 200 feet

0 100 200 Feet

NOTES:

1. 2015 orthoimagery obtained from the United States Department of Agriculture's (USDA), National Agriculture Imagery Program (NAIP).
2. Vegetation transect survey performed by Princeton Hydro, LLC.

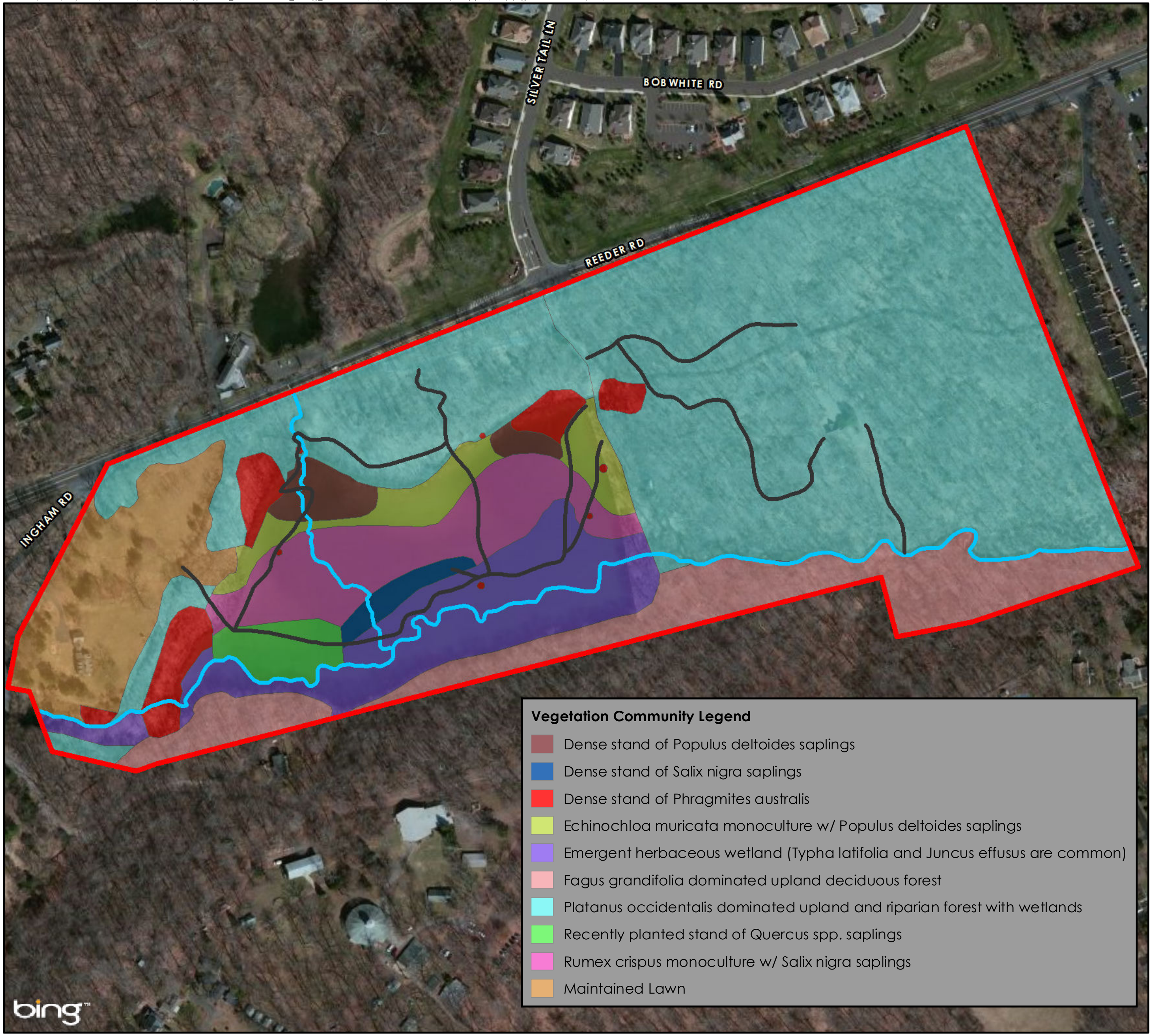
Map Projection:
NAD 1983 StatePlane Pennsylvania South FIPS 3702 Feet

VEGETATION TRANSECT LOCATIONS

AQUETONG CREEK
SOLEBURY TOWNSHIP
BUCKS COUNTY, PENNSYLVANIA

Legend

Transect



NEW JERSEY COUNTY MAP

PRINCETON HYDRO, LLC.
1108 OLD YORK ROAD
P.O. BOX 720
RINGOES, NJ 08551
*with offices in NJ, PA and CT

1 inch = 300 feet

0 150 300 Feet

NOTES:

1. 2011 aerial imagery obtained through ArcGIS Online Bing Maps (C) 2016 Microsoft Corporation and its data suppliers.

2. Vegetation community extents are approximate. Vegetation community locations observed by Princeton Hydro, LLC.

Map Projection:
NAD 1983 StatePlane Pennsylvania South FIPS 3702 Feet

VEGETATION COMMUNITIES MAP

AQUETONG SPRING PARK
SOLEBURY TOWNSHIP
BUCKS COUNTY, PENNSYLVANIA

Legend

- Property Boundary
- Walking Path
- Stream

Appendix D: USGS StreamStats Report

StreamStats Version 3.0

Flow Statistics Ungaged Site Report

Date: Fri Jan 20, 2017 9:26:39 AM GMT-5
Study Area: Pennsylvania
NAD 1983 Latitude: 40.3551 (40 21 18)
NAD 1983 Longitude: -74.9914 (-74 59 30)
Drainage Area: 0.21 mi2
2001 NLCD Impervious: 0.0 percent

Low Flow Basin Characteristics			
100% Low Flow Region 1 (0.21 mi2)			
Parameter	**Value**	**Regression Equation Valid Range**	
		Min	**Max**
Drainage Area (square miles)	0.21 (below min value 4.78)	4.78	1150
Mean Basin Slope degrees (degrees)	4.4	1.7	6.4
Depth to Rock (feet)	4.2	4.13	5.21
Percent Urban (percent)	0.0	0	89

Warning: Some parameters are outside the suggested range. Estimates will be extrapolations with unknown errors.

Mean/Base-flow Basin Characteristics			
100% Statewide Mean and Base Flow (0.21 mi2)			
Parameter	**Value**	**Regression Equation Valid Range**	
		Min	**Max**
Drainage Area (square miles)	0.21 (below min value 2.26)	2.26	1720
Mean Basin Elevation (feet)	253.0	130	2700
Mean Annual Precipitation (inches)	45.0	33.1	50.4
Percent Carbonate (percent)	100.0 (above max value 99)	0	99
Percent Forest (percent)	85.0	5.1	100
Percent Urban (percent)	0.0	0	89

Warning: Some parameters are outside the suggested range. Estimates will be extrapolations with unknown errors.

Peak Flow Basin Characteristics			
100% Peak Flow Region 1 (0.21 mi2)			
Parameter	**Value**	**Regression Equation Valid Range**	
		Min	**Max**
Drainage Area (square miles)	0.21 (below min value 1.72)	1.72	1280
Mean Basin Elevation (feet)	253.0	0	1960
Percent Carbonate (percent)	100.0 (above max value 83)	0	83
Percent Urban (percent)	0.0	0	20
Percent Storage (percent)	0.0	0	21.2

Warning: Some parameters are outside the suggested range. Estimates will be extrapolations with unknown errors.

Low Flow Statistics						
Statistic	**Value**	**Unit**	**Prediction Error (percent)**	**Equivalent years of record**	**90-Percent Prediction Interval**	
					Min	**Max**
M7D2Y	0.0223	ft3/s				
M30D2Y	0.0324	ft3/s				
M7D10Y	0.00756	ft3/s				

M30D10Y	0.0119	ft3/s				
M90D10Y	0.0222	ft3/s				

http://pubs.usgs.gov/sir/2006/5130/ (http://pubs.usgs.gov/sir/2006/5130/)
Stuckey_ M.H._ 2006_ Low-flow_ base-flow_ and mean-flow regression equations for Pennsylvania streams: U.S. Geological Survey Scientific Investigations Report 2006-5130_ 84 p.

Mean/Base-flow Statistics						
Statistic	Value	Unit	Prediction Error (percent)	Equivalent years of record	90-Percent Prediction Interval	
					Min	Max
QA	0.29	ft3/s				
QAH	0.32	ft3/s				
BF10YR	0.3	ft3/s				
BF25YR	0.27	ft3/s				
BF50YR	0.25	ft3/s				

http://pubs.usgs.gov/sir/2006/5130/ (http://pubs.usgs.gov/sir/2006/5130/)
Stuckey_ M.H._ 2006_ Low-flow_ base-flow_ and mean-flow regression equations for Pennsylvania streams: U.S. Geological Survey Scientific Investigations Report 2006-5130_ 84 p.

Peak Flow Statistics						
Statistic	Value	Unit	Prediction Error (percent)	Equivalent years of record	90-Percent Prediction Interval	
					Min	Max
PK2	18.1	ft3/s				
PK5	34.4	ft3/s				
PK10	47.8	ft3/s				
PK50	83.7	ft3/s				
PK100	102	ft3/s				
PK500	152	ft3/s				

http://pubs.usgs.gov/sir/2008/5102/ (http://pubs.usgs.gov/sir/2008/5102/)
Roland_ M.A._ and Stuckey_ M.H._ 2008_ Regression equations for estimating flood flows at selected recurrence intervals for ungaged streams in Pennsylvania: U.S. Geological Survey Scientific Investigations Report 2008-5102_ 57p.

Appendix E: Tables summarizing Fish and Macrobenthic Invertebrate Survey Data

Table 1. In-Situ water quality monitoring and flow data for Aquetong Creek, August 2017.

***In-Situ* Monitoring and Flow Data for Aquetong Creek, August 2017**									
Station	**Transect Width**	**Average Depth**	**Depth Sampled**	**Temperature**	**Specific Conductance**	**Dissolved Oxygen**		**pH**	**Discharge**
	Feet	**Feet**		**°C**	**mS/cm**	**mg/L**	**% Sat.**	**S.U.**	**gpm**
ST1	11.2	0.48	Surface	12.03	431.40	9.93	95.3	7.83	1880.16
ST2	26.9	0.54	Surface	12.09	431.30	9.97	95.8	7.81	2284.47
ST3	5.4	0.84	Surface	12.45	430.60	10.12	98.2	7.54	2541.01
ST4	2.92	0.18	Surface	20.56	628.30	8.84	97.6	8.11	20.79
ST5	4.8	0.51	Surface	11.99	429.50	9.86	94.6	7.70	1837.18

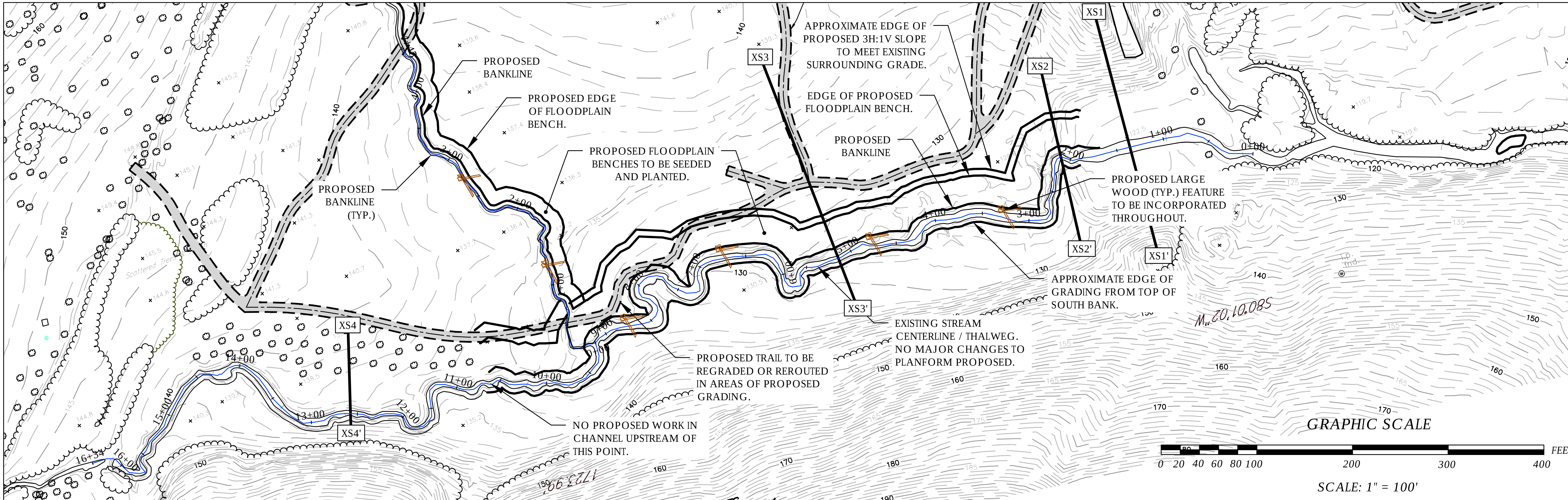
Table 2. Summary of Bioassessment with fish community data. Dominant species combine to make up 50% or more of the species composition and are noted in bold, italic text with an asterisk.

Fish Population for Aquetong Creek, August 2017								
Common Name	**Station 1**	**Station 2**	**Station 3**	**Statio n 4**	**Station 5**	**Total**	**Relative Abundance (# per acre)**	**Relative Abundance (# per hectare)**
American Eel	***5****	***13****	-	-	***1****	19	162	399
Black Nose Dace	-	1	-	-	-	1	9	21
Brook Trout	-	2	-	-	-	2	17	42
Green Sunfish	-	***9****	-	-	-	9	77	189
Largemouth Bass	-	1	-	-	-	1	9	21
Pumpkinseed Sunfish	-	5	-	-	-	5	43	105
Tesselated Darter	-	1	-	-	-	1	9	21
White Sucker	-	2	-	-	-	2	17	42
Abundance	**5**	**34**	**0**	**0**	**1**	40	340	841
Richness (# of taxa)	**1**	**8**	**0**	**0**	**1**	8	-	-
Evenness	1.00	0.79	0.00	0.00	1.00	0.77	-	-

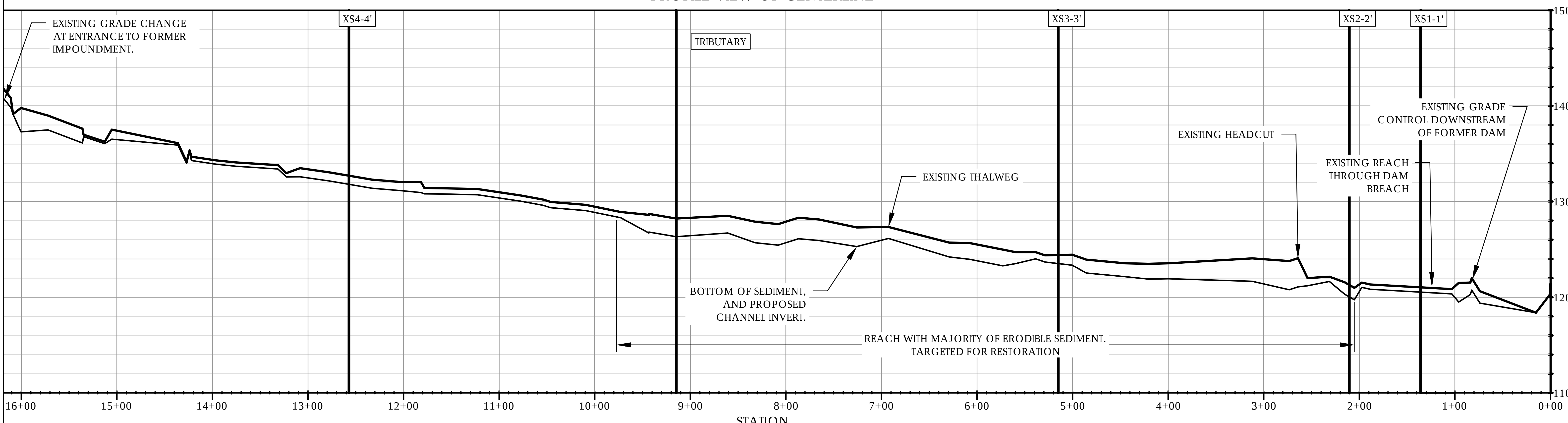
Table 3. Summary of Bioassessment with benthic invertebrate community data. Dominant taxa combine to make up 50% or more of the species composition. EPT species are organisms that are indicative of stream quality and include individuals from the orders Ephemeroptera, Coleoptera, and Tricoptera.

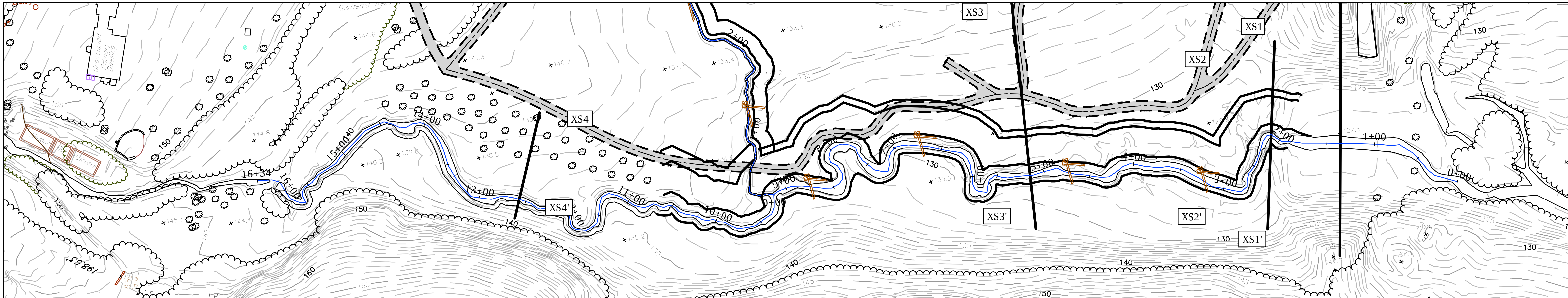
Benthic Invertebrates for Aquetong Creek, August 2017					
Station	**Relative Abundance**	**Richness (# of taxa)**	**Evenness**	**Dominant taxa**	**% EPT species**
ST1	203	7	0.81	Amphipoda, Ephemeroptera	24.6%
ST2	200	8	0.68	Amphipoda, Ephemeroptera	30.0%
ST3	50	8	0.74	Amphipoda, Ephemeroptera	18.0%
ST4	32	10	0.79	Diptera, Hemiptera	6.25%
ST5	50	5	0.36	Amphipoda	6.0%

Appendix F: Conceptual Restoration Design Plans



PROFILE VIEW OF CENTERLINE





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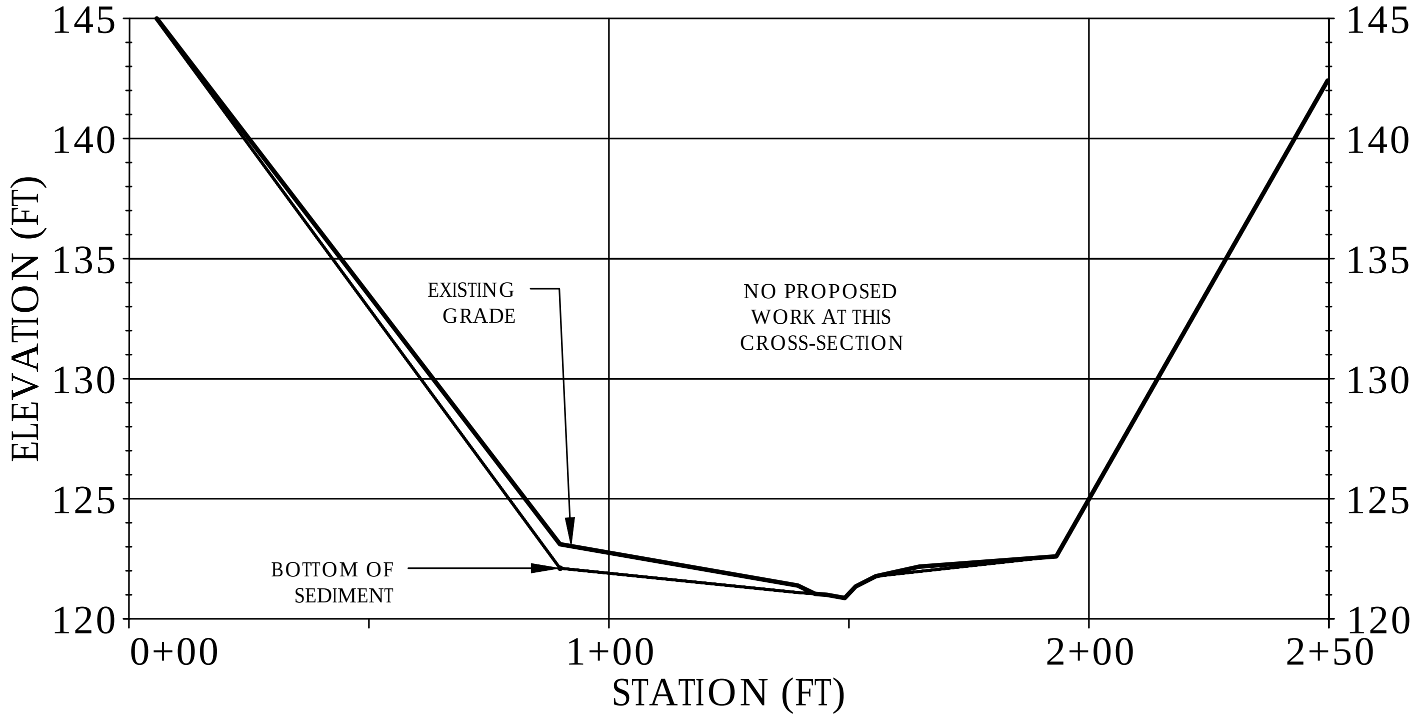
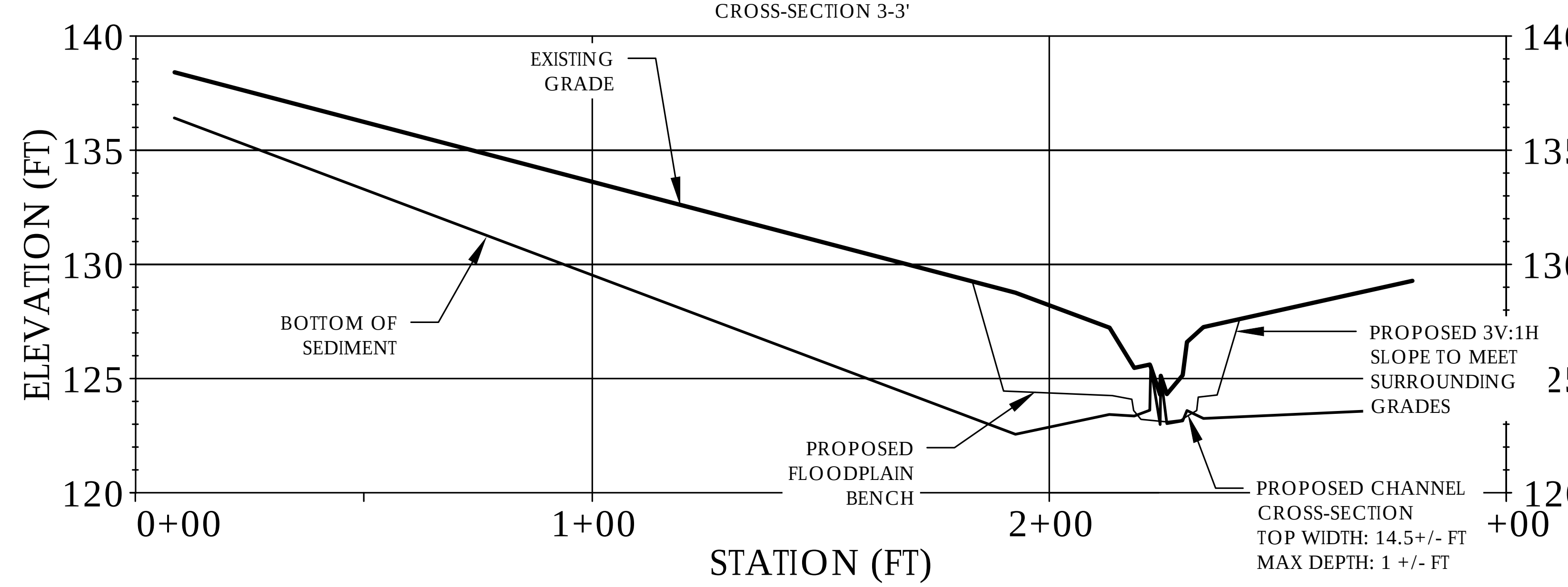
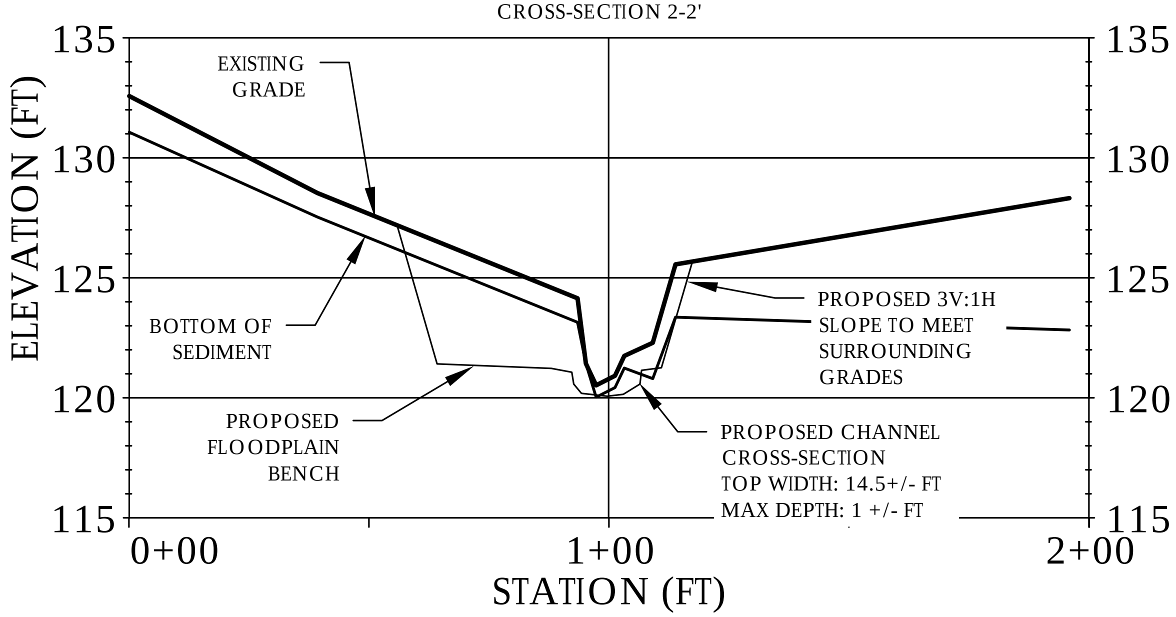


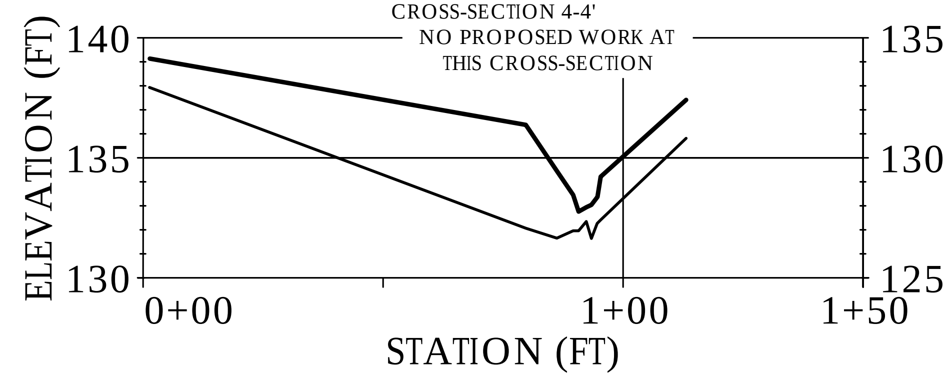
CROSS-SECTION 3-3'

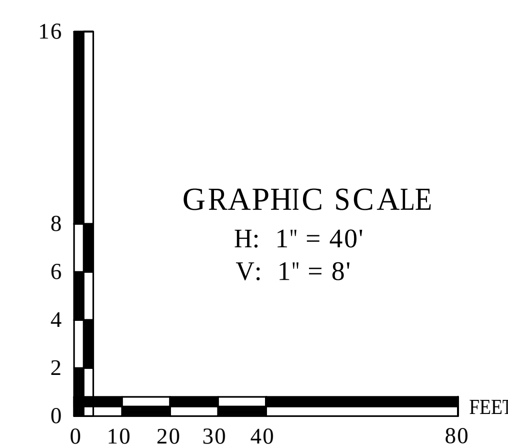


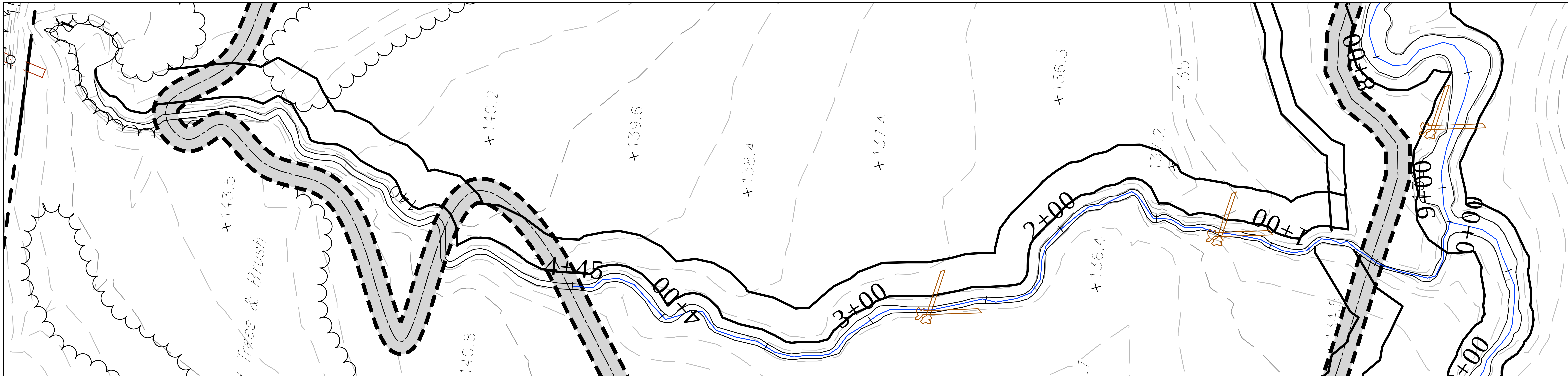
CROSS-SECTION 2-2'



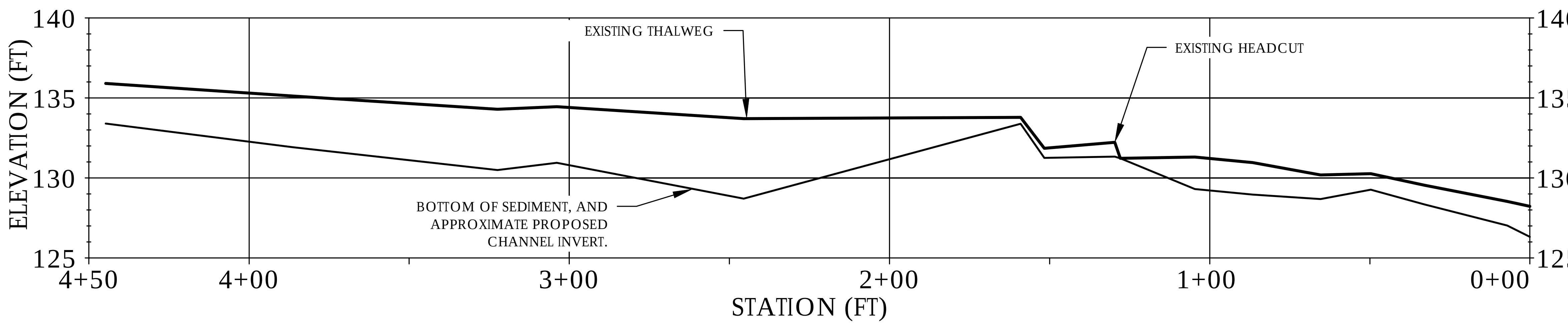
CROSS-SECTION 4-4'
NO PROPOSED WORK AT
THIS CROSS-SECTION



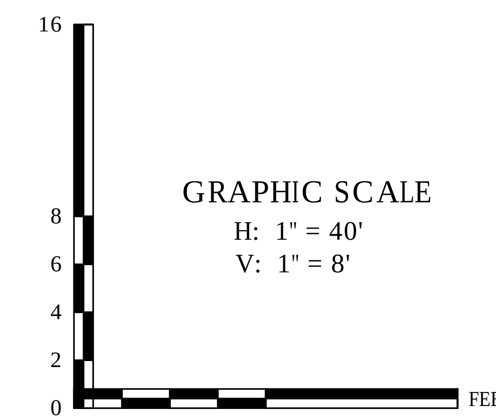


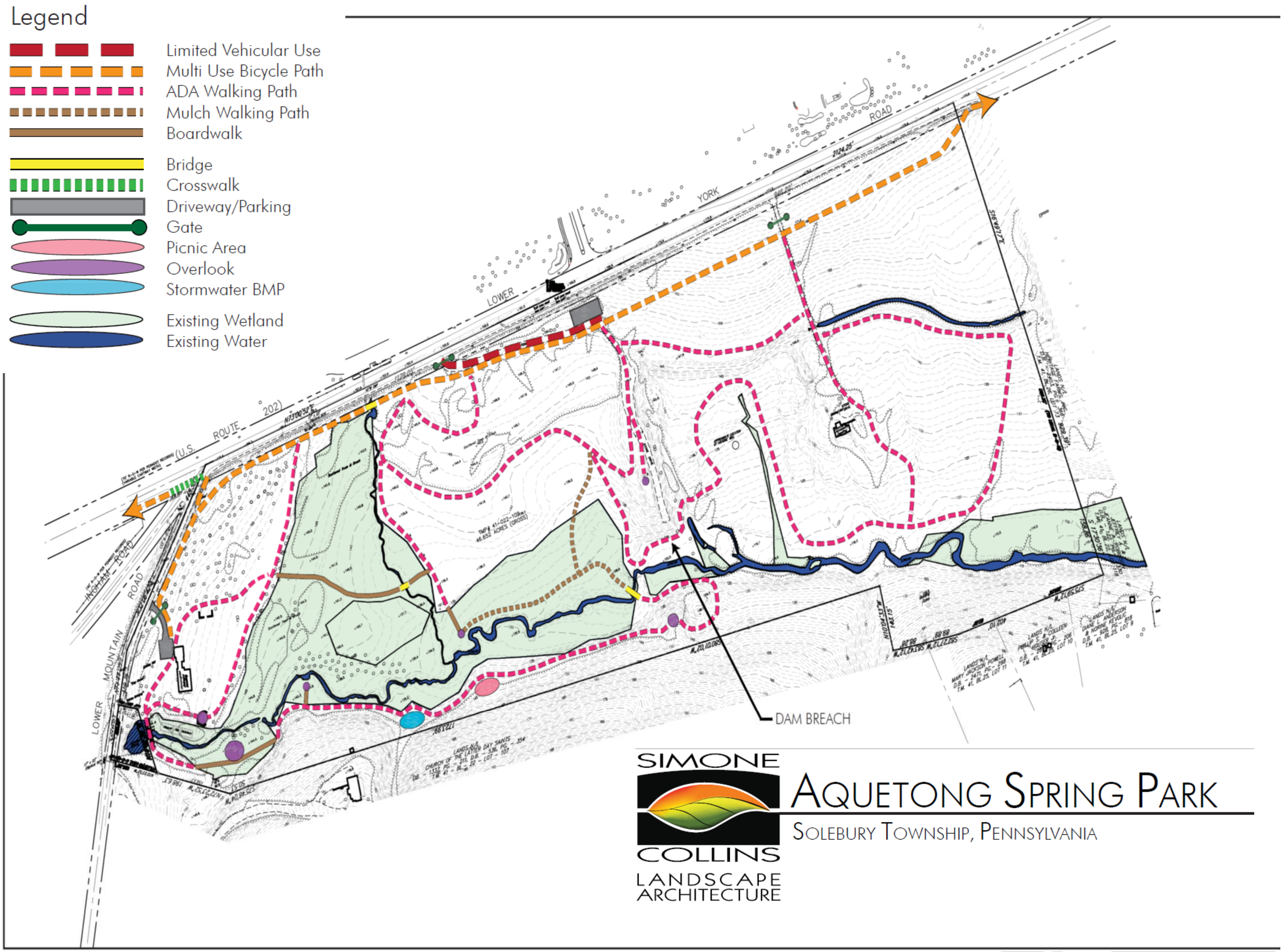


TRIBUTARY PROFILE



CROSS-SECTION 2-2'




Legend
Limited Vehicular Use
Multi Use Bicycle Path
ADA Walking Path
Mulch Walking Path
Boardwalk
Bridge
Crosswalk
Driveway/Parking
Gate
Picnic Area
Overlook
Stormwater BMP
Existing Wetland
Existing Water
LOWER YORK ROAD
(U.S. ROUTE 202)
LOWER MOUNTAIN ROAD
INGHAM ROAD
DAM BREACH
SIMONE COLLINS
LANDSCAPE ARCHITECTURE
AQUETONG SPRING PARK
SOLEBURY TOWNSHIP, PENNSYLVANIA