Griswold Creek Watershed Restoration Plan

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In cooperation with EnviroScience, Inc.

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ABSTRACT

Griswold Creek is a coldwater stream in the Chagrin River watershed that has experienced severe erosion. To determine appropriate restoration opportunities and details for Griswold Creek, Chagrin River Watershed Partners, Inc. (CRWP) and our selected subcontractor, EnviroScience, Inc. collected data on channel dimensions and slope in stable and impaired sections of Griswold Creek. The investigation documented and summarized existing conditions and identifies possible restoration measures to restore natural stream function and stability. EnviroScience developed a longitudinal profile that shows slope changes over the length of the stream and a regional curve that relates the cross-sectional area of the channel to the drainage area of the watershed. EnviroScience used this information to prepare conceptual restoration plans for two sites on Griswold Creek. The conceptual plan for the upstream site involves building up the streambed to its former elevation to reconnect it with its floodplain and promote stormwater storage in the existing riparian wetland. The conceptual plan for the downstream site incorporates streambank stabilization techniques with floodplain expansion. The conceptual plans include graphics, conceptual engineering details, and cost estimates. CRWP will continue to assist property owners in developing grant proposals to complete construction on these projects.

BACKGROUND

Griswold Creek is located in Chester and Russell Townships in Geauga County and flows into the Chagrin River in the Village of Hunting Valley in Cuyahoga County. The Ohio Environmental Protection Agency (EPA) designated Griswold Creek as a cold water habitat stream. Griswold Creek maintains a unique biological community and a cold stream temperature due to significant amounts of groundwater feeding the stream. At Fairmount Road, Griswold Creek is in partial attainment of the cold water habitat use, but the lower reach at Falls Road is in non attainment. Ohio EPA noted habitat alteration and thermal modifications as causes of non attainment. The sources of these impairments are discharges from wastewater treatment plants, suburban development, streambank modification, removal of riparian vegetation, and nonpoint source stormwater runoff.

Despite these impairments, Griswold Creek is home to the redside dace (*Clinostomus elongates*), a declining fish species in Ohio. The redside dace favors slow moving cool, clear headwater streams with good riffle-pool development and overhanging riparian vegetation such as grasses, forbs, and low shrubs. The species is declining in Ohio and has dwindled in many areas of its range, including the Great Lakes. The redside dace is listed as endangered in Indiana and Ontario, as threatened in Michigan, and as special concern in Wisconsin.

Griswold Creek is also experiencing severe erosion. CRWP and Geauga SWCD have been asked by numerous property owners to make recommendations regarding erosion on their property along Griswold Creek. One property at 44001 Falls Road in Hunting Valley experienced a lateral loss of 40 feet of riparian land in six years due to erosion. This stream is impacted by the breach of two privately owned dams in 1989-1990, the existence of at least 6 lowhead dam features, and other watershed development. Russell Township and Hunting Valley designated the Griswold Creek corridor as Priority Conservation Areas in the *Chagrin River Watershed Balanced Growth Plan.* Both Russell Township and Hunting Valley adopted riparian setback regulations that limit development near the creek and promote protection of this corridor.

Several landowners have attempted to address streambank erosion issues; however, these small scale fixes are often impacted by stream flows and have not been effective. This study represents a watershed approach that promotes the implementation of stable stream channel characteristics and sustainable solutions.

METHODS

Chagrin River Watershed Partners, Inc. (CRWP) and our consultant EnviroScience, Inc. investigated the stability of Griswold Creek by conducting site visits, evaluating the longitudinal profile of the entire stream, evaluating erosion severity at 6 locations, and generating a regional curve relating channel cross-sectional area to drainage area. CRWP and EnviroScience visited 12 properties along Griswold Creek as part of this project (Figure 1). The longitudinal profile was created using LIDAR topographic data and CRWP's GIS data. Erosion severity was evaluated using the Bank Erosion Hazard Index (Rosgen, 2001) at 6 sites. The Bank Erosion Hazard Index provides a numeric and narrative erosion severity evaluation that incorporates bank height, plant rooting depth and root density, bank angle, surface protection of the toe of the bank by rock or wood, and bank composition and stratification. Erosion severity was evaluated at the most severely eroding location on each property. The regional curve was created by measuring channel dimensions at 6 locations along Griswold Creek and two locations in a nearby watershed with similar characteristics.

Stream channel measurements were taken at impaired sites and a reference site in relatively stable condition. The measurements included channel dimensions, slope, stream pattern, and streambed particle size (Figures 2 and 3). EnviroScience used the survey data to develop conceptual restoration plans for two impaired sites. Because the case study sites have typical issues occurring in the creek, the conceptual restoration plans and developed regional curve offer solutions that are applicable to multiple areas.

Figure 1: Locations of Site Visits, Conceptual Restoration Plan Sites, and Reference Site

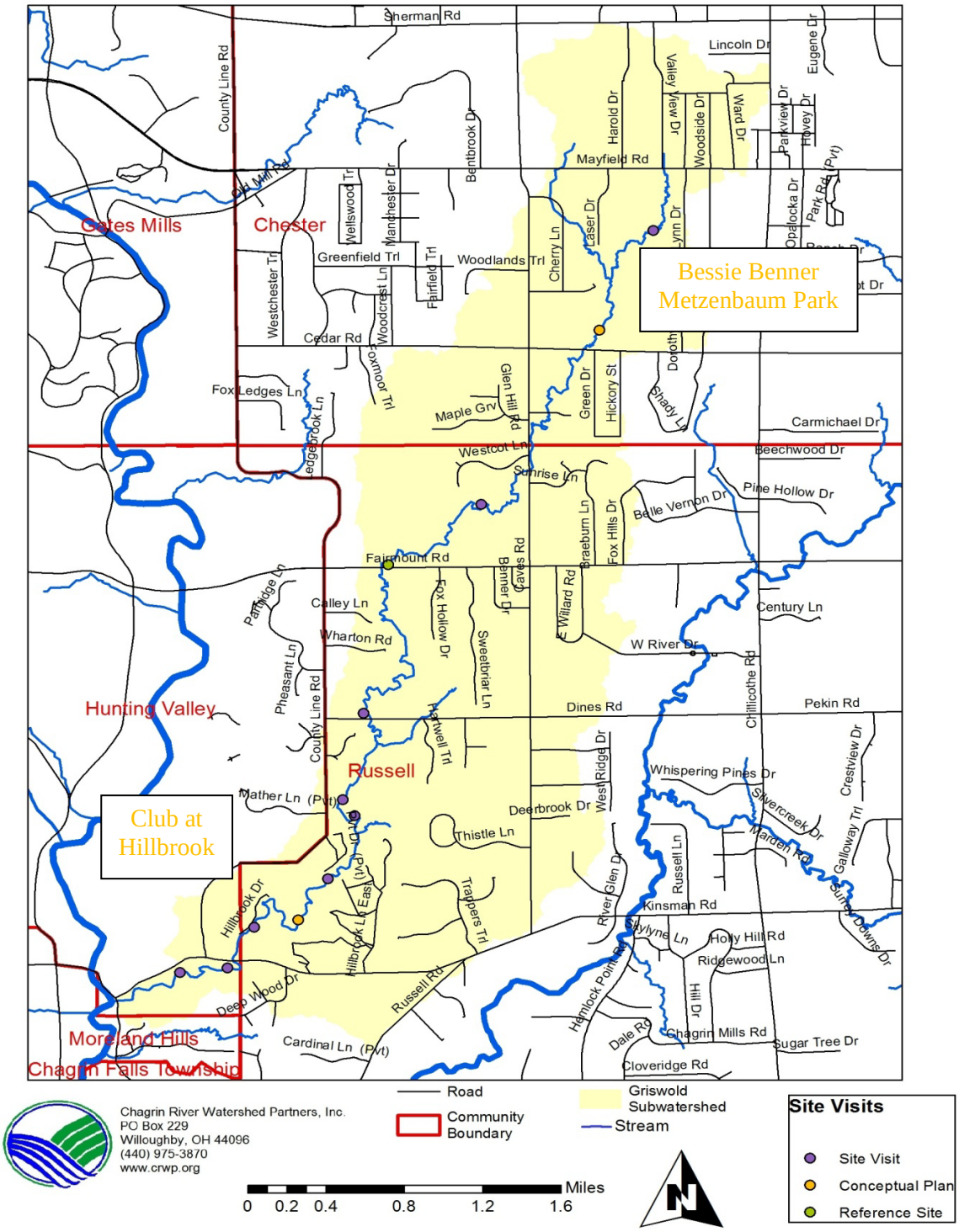


Figure 2: EnviroScience staff members documenting channel slope as part of a longitudinal profile along a reach of Griswold Creek.

Figure 3: Joel Bingham of EnviroScience noting channel dimensions across a cross-section of Griswold Creek at Geauga Park District's Bessie Benner Metzenbaum Park

RESULTS & DISCUSSION

The longitudinal profile indicates that a section between Fairmount and Dines Roads is the flattest section of Griswold with a 0.25% slope and the section closest to the mouth is the steepest, with a 1.1% slope (Figure 3). Different restoration techniques may be needed in the flattest sections than in the steepest sections.

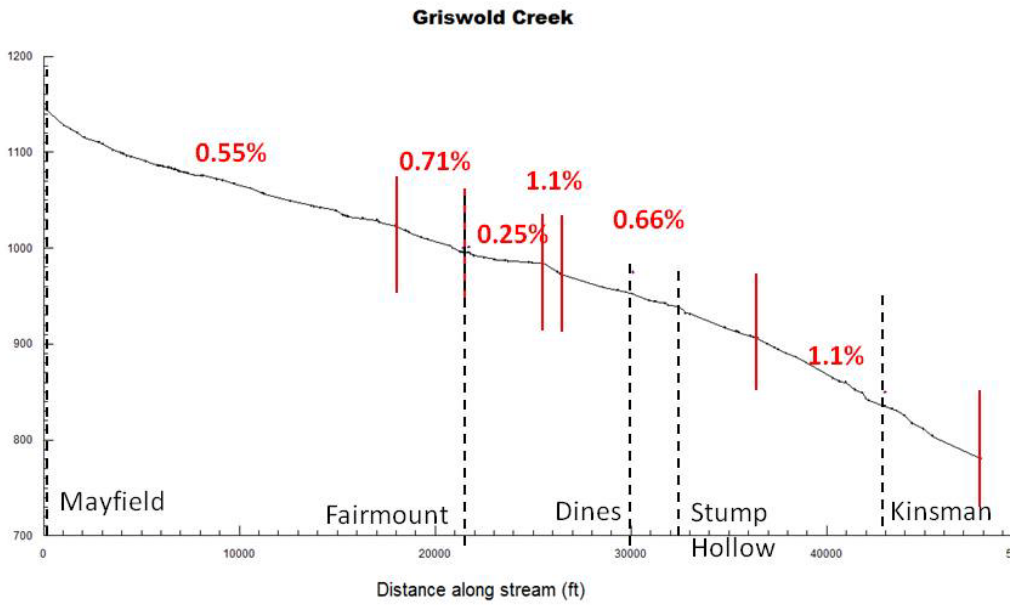


Figure 3: Longitudinal profile of Griswold Creek. Slope breaks and labels are red. Street crossings are indicated with black dotted lines and black text.

In most locations including the reference reach at Laurel School by Fairmount Road, the stream is classified as a type C channel, although it is a type E channel at Bessie Benner Metzenbaum Park (Rosgen 1994). Type C channels are relatively low gradient meandering streams with riffle-pool morphology. The dominant bed material is cobble at the reference reach location. The substrate is similar at most locations except for a reach in Chester Township that is sandy and a reach in Hunting Valley that has bedrock substrate. Extreme erosion was identified at 3 properties (Figure 4). Some properties had both eroding and stable sections of Griswold Creek. Recommendations resulting from site visits are presented in Table 1.

Cross-sectional area varied from 16.5 ft^2 to 100.2 ft^2 at surveyed locations along Griswold Creek (Figure 5). EnviroScience scientists developed a regional curve that defines the relationship between channel cross-sectional area to drainage area with a formula that can be used as a starting point for restoration designs. This regional curve can help property owners throughout the Griswold Creek subwatershed in developing restoration plans that will promote stable stream channels.

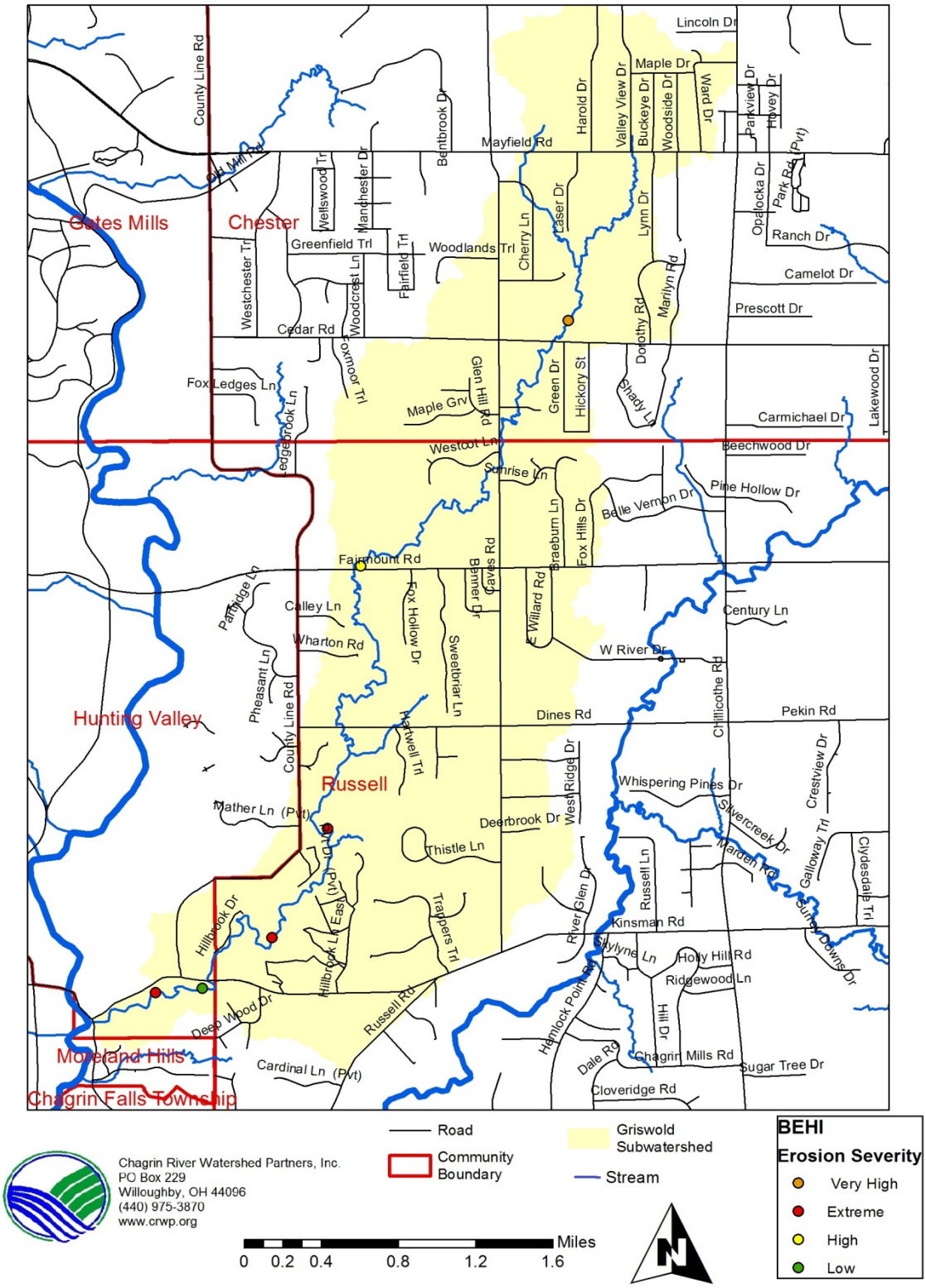
Table 1: Site Visits, Conceptual Restoration Plans, and Reference Sites on Griswold Creek

Site	Parcel #	Recommendations
Valley View WWTP	11-714404	Possibly raise grade. Would need to coordinate with WWTP.
Bessie Benner Metzenbaum	11-711400	Raise grade & restore hydrologic connection to riparian wetland. See concept plan.
Rivendell	26-214273	Raise grade to expand floodplain access.
Laurel School	26-707033	Reference site. Tree revetment for small eroding area.
Russell Township Park	26-707017	Allow small debris dams to accumulate for grade control.
Luzius	26-213854	Floodplain expansion
Thornberry	26-003310	Floodplain expansion & bank stabilization
Davis	26-168700	Lower roadbed or stabilize toe
Club at Hillbrook	26-028780	Floodplain expansion & bank stabilization
Bowen	26-181000	Stabilize toe of lowhead dam
Connor & Bookman	88223006 &8822401	Connor: slope stabilization Bookman: use vegetation for previously completed bank stabilization
Weisberg	88225008	Stream on bedrock. Control roof runoff to limit slope erosion.

The conceptual plans use case studies to illustrate appropriate restoration techniques for this watershed (Appendix A). At Geauga Park District's Bessie Benner Metzenbaum Park in the upper reaches of the stream, the recommendation restoration strategy is raising grade to reconnect with the historic floodplain and restore the hydrologic connection between the stream and the wetland. The stormwater storage provided by this restoration activity would benefit downstream property owners by decreasing the frequency and intensity of erosive flow events. Restoration recommendations for the downstream reaches at The Club at Hillbrook include bank stabilization with large rock and native plantings and floodplain expansion.

CRWP and EnviroScience presented the results of this study at a public meeting held at Russell Township Hall on August 22, 2013. This presentation is available on CRWP's website: http://www.crwp.org/index.php/projects/restoration-projects-current/griswold-creek-streambank-stabilization.

Figure 4: Erosion severity along Griswold Creek in Chester, Russell, and Hunting Valley



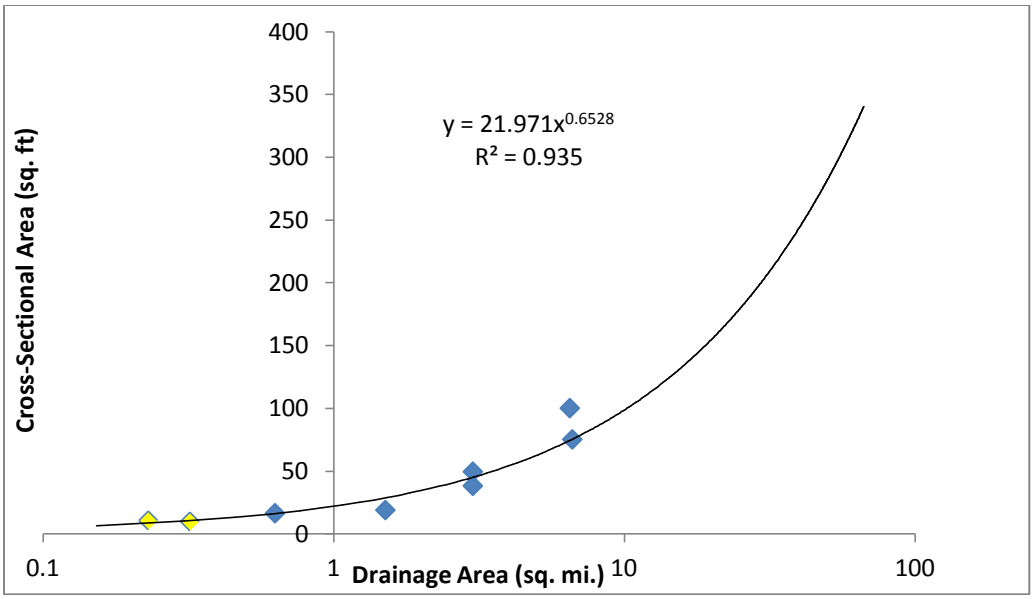


Figure 5: Regional curve presenting channel cross-sectional area as a function of drainage area. Yellow diamonds represent sample points taken in a nearby watershed. Blue diamonds represent survey points on Griswold Creek.

NEXT STEPS

Through a Great Lakes Basin Program for Soil Erosion and Sediment Control grant, CRWP will be able to offer a small amount of financial assistance for landowners along Griswold Creek to complete streambank stabilization projects. The conceptual restoration plans and typical engineering designs produced through this Lake Erie Protection Fund project will inform the design of the streambank stabilization projects completed. CRWP will work with other interested landowners to pursue additional funding for restoration projects along Griswold Creek.

CRWP will continue to assist the communities in the Griswold Creek watershed with adopting best local land use practices. Russell and Hunting Valley already have riparian setbacks and Russell and Chester have comprehensive stormwater and erosion and sediment control regulations. CRWP is updating its comprehensive stormwater and erosion and sediment control model codes to reflect the changes to the construction general stormwater permit and will share these updated model codes with Chester, Russell, and Hunting Valley.

CONCLUSIONS

Griswold Creek is undergoing active channel adjustment. The stream channel is trying to go through the channel evolution process and create a new floodplain at the new lower elevation of the stream. Griswold Creek would benefit from increased floodplain access and storage of water in wetlands, especially in the upper part of the watershed. South of Dines Road, several areas have grade control structures that are preventing the stream in that area from downcutting. These grade control structures should be maintained or replaced with more natural grade control structures to prevent downcutting and channel widening in these areas.

This project provides conceptual details for two sites with different approaches to stream restoration. In addition, the developed regional curve can be used by property owners,

restoration designers, and CRWP to properly size stream channels during stream restoration design and construction. CRWP will continue to work with property owners throughout this subwatershed on sustainable solutions to stream bank erosion and channel stability.

REFERENCES

Rosgen, D. L. (1994). A classification of natural rivers. *Catena*, *22*(3), 169-199.

Rosgen, D. L. (2001, March). A practical method of computing streambank erosion rate. In *Proceedings of the Seventh Federal Interagency Sedimentation Conference* (Vol. 2, No. 2, pp. 9-15).

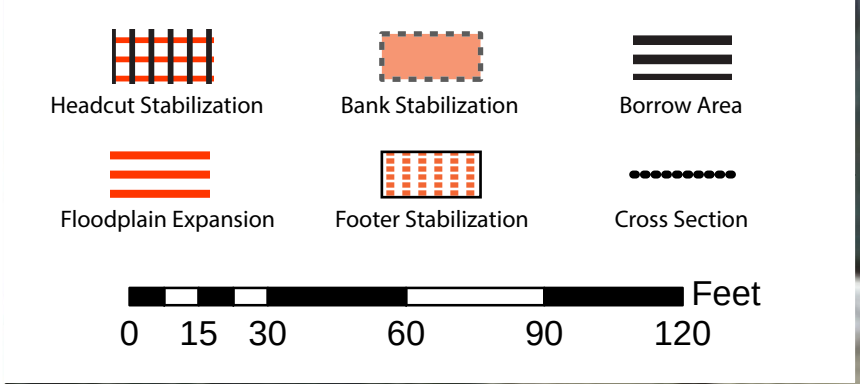
Griswold Creek Restoration

Hillbrook Club

Watershed Area: 6.51 mi^2

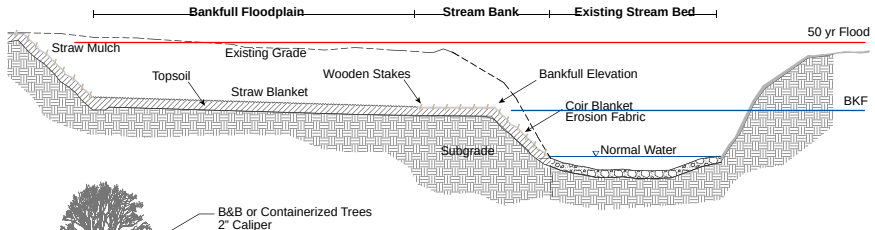
At the Hillbrook Club, Griswold Creek is characterized by unstable banks and man-made flow control structures. The instability and erosion further disconnects the creek from its floodplain during storm events.

To return the creek to a functional and stable condition, Enviroscience proposes a two phase restoration process. In the first phase, the banks will be stabilized with large stone, erosion matting and native plantings. The second phase consists of a 0.47 acre (20,600 ft^2) floodplain expansion and the removal of several gabion walls which will add valuable floodprone area to the stream system. The floodplain would temporarily slow and treat stormwater if it overflows the riverbank, improving the water quality and bank stability downstream. The lush plantings would provide a safe and colorful backdrop to Club events and activities.



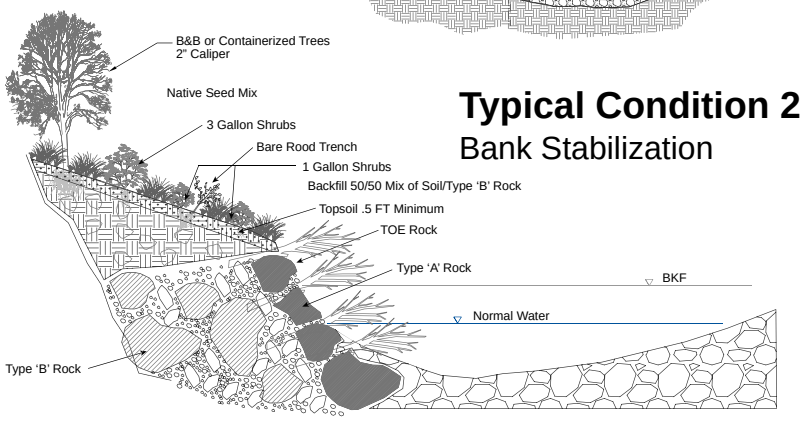
Typical Condition 1

Floodplain Expansion

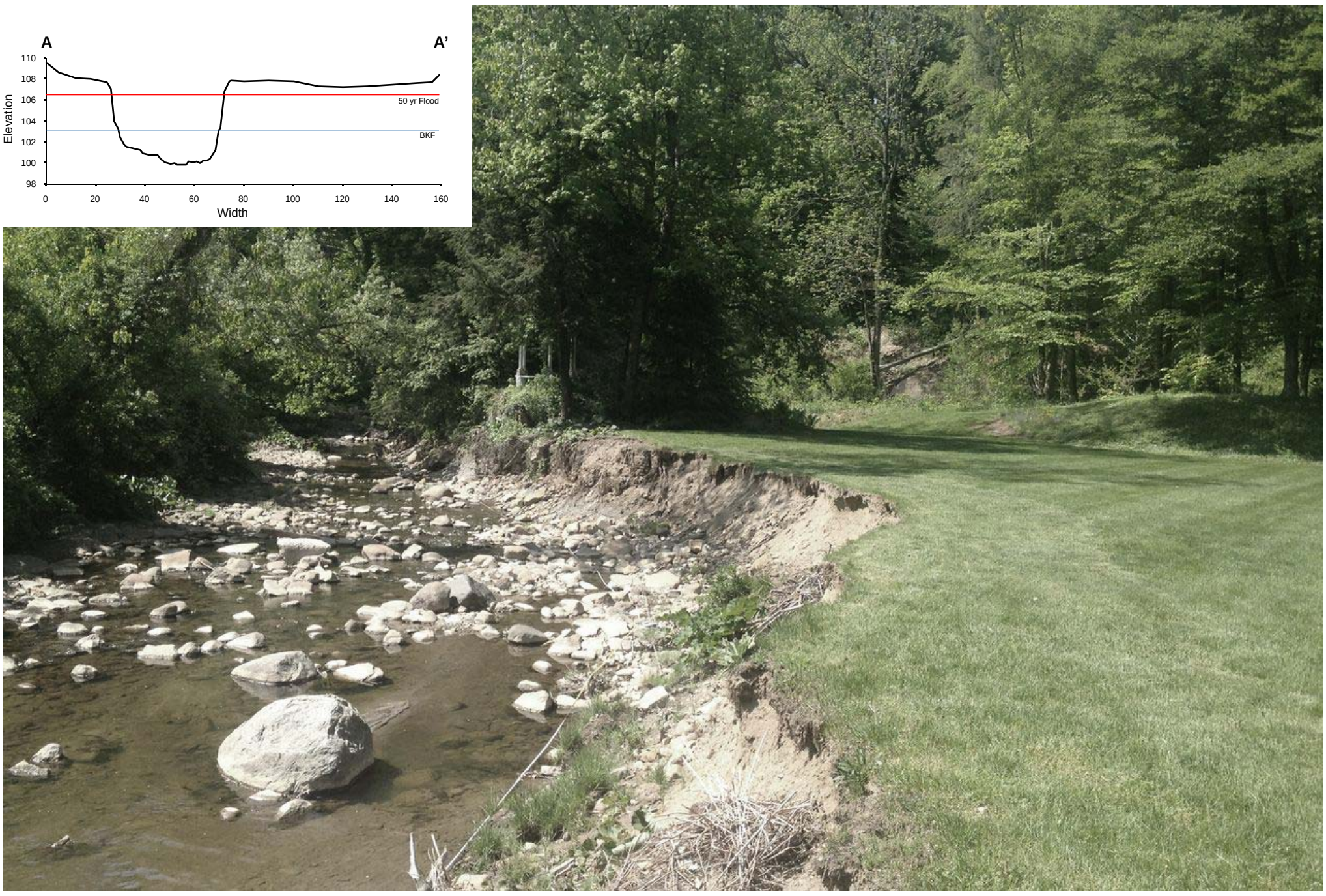


Typical Condition 2

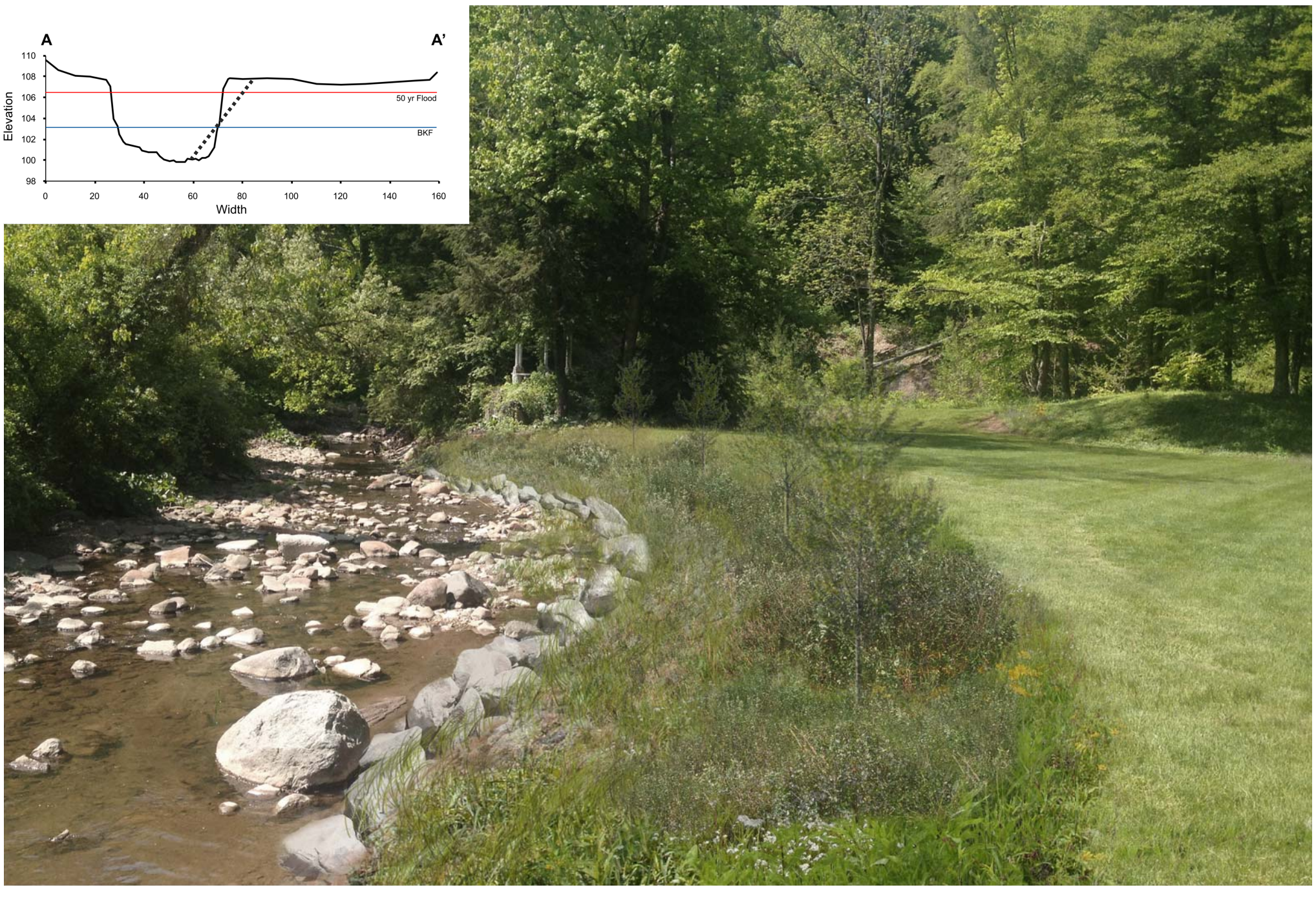
Bank Stabilization



Existing Condition



Bank Stabilization



Griswold Creek
The Club at Hillbrook

The following are additional details for the conceptual restoration plan for Hillbrook Club.

Bank Stabilization (~100 ft)

The wedding lawn area has been eroding as the stream channel widens its course through Hillbrook Club. Analysis of the reach determines that the area will continue to erode because of unstable conditions. The existing stream bank and opposite bank are approximately 6.6 ft vertical banks. The widening process is part of a systemic channel adjustment in this reach to create a new floodplain at a lower elevation. Downstream of the historic dam location this process is further along and floodplain development is more evident by the greater width of the valley and vegetation growing approximately 2-3ft above the base waterline.

The proposed bank stabilization along the wedding lawn returns some of the basic foundations of bank stability namely toe stability, bank slope and vegetation. The toe rock is important for creating a stable foundation for material bankfill in order to achieve a suitable slope for planting vegetation. A more gradual the bank slope (minimum 2:1) is better for dissipating erosive forces as well as growing vegetation. A shift in vegetation is necessary to encourage native plants with a greater rooting depth and capacity to hold soils. The proposed slope grading of 3:1 is a balance between reclaiming lost streambank and additional grading into the wedding lawn area because a total bank reclamation would be working directly against the trending river evolution of widening. The borrow area identified to the south of the stabilization site will be used for a source of subgrade material for this bank section. Toe rock and topsoil would be imported to the site.

Bank stabilizations are often just “patch” fixes within the midst of a larger problem. Also, many bank stabilizations fail to look directly across the river to areas where additional forces could be mitigated with the creation of floodplain. Recognition of the fact that the river is attempting to create floodplain is the main reason why a floodplain expansion has been proposed. A bank stabilization project working in tandem with floodplain creation will create a more sustainable solution for long-term stability.

Floodplain Expansion (0.25 acre)

Griswold Creek has lost access to its historic floodplain and therefore is undergoing a channel evolution process. Currently the channel it is widening through erosion and a majority of the stormwater flows are contained within the 6-7 ft high streambanks. The confinement of stormwater flow creates excess power due to depth of water. This power can move large quantities and sizes of material. Floodplains act to dissipate energy by reducing the flood stage height and spreading out flows. The proposed area currently depicted on the concept plan is an

attempt to maximize this floodplain area. If budget or other constraints are discovered, this area can always be reduced or modified. A larger floodplain is obviously more beneficial, but any floodplain will be helpful to the long-term stability of the system. It is also important to note that the river channel itself should not be overwide. This will create a loss of sediment transport competency and be counterproductive to restoration efforts. Any activity in the channel whether from bank stabilization or floodplain expansion should evaluate the width:depth ratio (W:D) of the channel as well as entrenchment ratio. The existing cross section at the site has a W:D of 15.9. Other reaches of Griswold Creek showing more stable conditions exhibit a W:D of 15-24. So the W:D ratio may be sufficient for sediment transport in its current dimension. The entrenchment ratio is greater than 2.2. That would require a floodprone width of approximately 90ft. Currently that is proposed for one area on the concept plan (the wide area between the tennis courts). However, this width becomes constricted to approximately 75-80ft of potential at the cross section location. This would create an entrenchment ratio of 1.8 which is considered moderately entrenchment. Just downstream past the historic dam location the channel has widened considerably more that directly adjacent to the wedding lawn. The floodprone widths in this area range from 75 in the straight section and 110ft around the meander. These sections are not necessarily stable but give an indication of the trend for additional floodplain space. Ultimately any floodplain that can be achieved through the site will be beneficial.

Remove Gabions

At several locations, failed gabions have fallen into the channel. The locations identified are areas where failed gabions are creating detrimental flow conditions or sediment aggradation. During the floodplain expansion process, machines would be in close enough proximity to remove the gabions from the channel.

Stabilize Headcut

Headcut erosion is generally caused by a larger mainstem stream that has downcut from a historic stream bed elevation. This situation has occurred in the Griswold Creek watershed. Consequently, all tributaries that confluence with the mainstem have begun a channel evolution process. A small intermittent tributary flowing from the east is undergoing this process. Currently the headcut has moved about 50ft up from the mainstem. In conjunction with the floodplain expansion it is recommended that this headcut be stabilized to prevent additional down cutting. The methods proposed to do this would include the import of large stone and wood to create a grade control structure that can dissipate the elevation drop. At the same time the incised banks of the small stream could be graded back and planted with vegetation to help stabilized soils. If left unattended, erosion will continue upstream creating channel incision and instability.

Stabilize Erosion-

There is one location downstream of the tennis pedestrian bridge that has experienced some considerable erosion and bank failure. Eventhough this failure is fairly typical along the reach, this location is near the pedestrian bridge footers and end of the gabion treatments. This area has widened due to the same processes described above. The proposed fix with this area would be the back fill of large boulders at approximately half the bank height. The boulders will also help protect the exposed gabions upstream. It is anticipated that this work would occur during a stabilization effort of the pedestrian bridge footers.

Footer Stabilization-

The pedestrian bridge footers and the gabion protection are significantly undermined. The channel is widening upstream and downstream of the bridge and therefor the bridge span is creating a narrow constriction within the channel. This constriction is also causing some accumulation of sediment directly upstream. This large sediment bar is allowing the river to adjust to the east and will eventually work behind the eastern bridge footer. It is our opinion that a longer bridge span or significant armoring of the footers and banks will be necessary to convey the flow. The concept plan proposes a hard armoring of the footer area with large boulders to help protect from additional undermining. At the same time, an effort to redirect stream flow in-line with the bridge may be necessary by re-locating the sediment bar towards the east. This may provide some temporary relief to the channel migration but with an understanding that it could repeat the same lateral movement and deposition.

The Club at Hillbrook Conceptual Restoration Plan Cost Estimate

Task	**Estimated Cost**
Permitting	$7,825.00
Design	$28,779.41
Construction	147,602.27
Oversight	$7,640.00
Plants	$12,283.33
Totals	**$204,130.01**

Griswold Creek Restoration
Metzenbaum Site

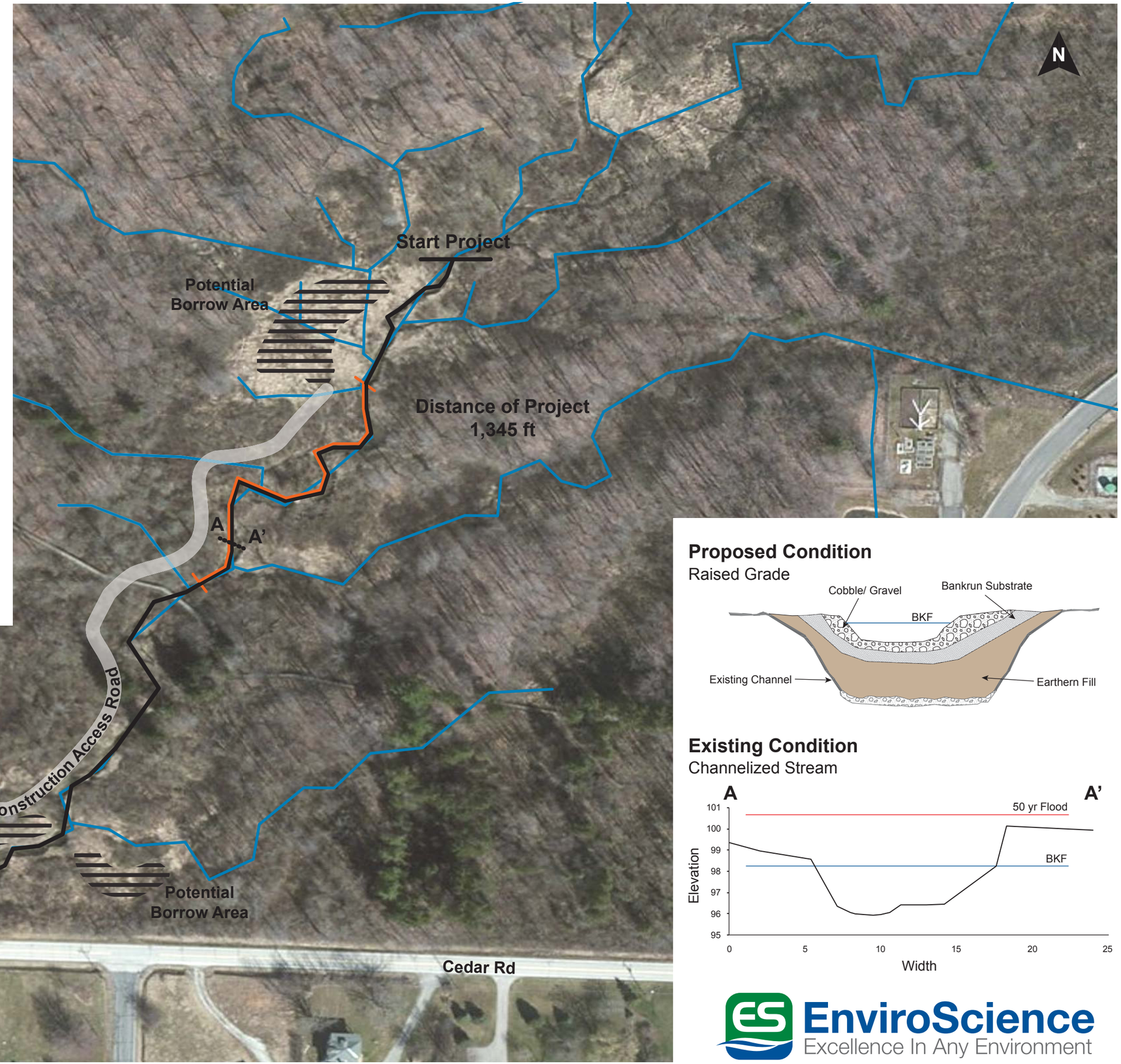
Watershed Area: 1.5 mi^2

Today, Griswold Creek at Bessie Benner Metzenbaum Park is an unstable stream system suffering from erosion and impaired water quality. As stormwater fills the channel, it destabilizes the banks and scours the substrate creating a deeper channel which further disconnects the floodplain.

In order to return the stream to a stable condition, Enviroscience proposes raising the grade of the existing channel back to a functional relationship with the historic floodplain. This process will connect the creek back to its floodplain and rehydrate the existing wetlands. During storm events, water will be stored adjacent to the stream in the wetlands where it will be filtered and slowly released over a lengthy period of time. Floodwater storage and treatment provides valuable ecological functions including flood protection and mitigation of downstream stormwater.

GIS Stream Location | Survey Reach | Length of Project

0 75 150 300 450 600 Feet



Proposed Condition
Raised Grade

Existing Condition
Channelized Stream

EnviroScience
Excellence In Any Environment

Existing Condition

Proposed Condition

Griswold Creek
Geauga Park District's Bessie Benner Metzenbaum Park

The following are additional details for the conceptual restoration plan for Bessie Benner Metzenbaum Park (Metzenbaum Park).

Stream Restoration-

Griswold Creek through Metzenbaum Park is moderately entrenched. The channel is narrow and typical of a wetland "E" channel but showing signs of channel adjustment and active floodplain creation below the historic floodplain wetland. Wetland streams with little natural grade control and finer grained substrates such as sand and silt are very susceptible to erosion and channel adjustment once floodplain access is lost. The proposed raise grade restoration will restore this regular connection and decrease erosion/channel adjustment potential. Secondarily it will increase wetland hydrology to enhance more wetland obligate species. However, the primary benefit of the restoration at this site is more for a watershed scale benefit of storm water storage and detention within a natural system. Downstream areas of Griswold Creek are undergoing channel evolution partly due to increased storm water runoff from development. Large wetland systems such as these are not being used to their fullest capacity once a stream loses its regular connection. This project is proposing 1,345 l.f. of stream restoration that entails the fill of earth and substrates to create a new streambed profile along the existing stream alignment. Conceptual design dimensions of the channel should reflect a width:depth ratio appropriate for an "E" type channel. This would be a range from 8-12 with an average of 10 as a target. Channel widths of 13-15 ft with a mean depth of 1.2 to 1.4. Substrates would have to be imported material consisting of mixture of sand, gravel and cobble. It is recommended that the imported substrate be of a slightly larger size than that of the alluvial substrates and the channel dimensions be sized to move the upstream bedload supply. The larger material will provide additional grade control. Final substrate size and composition should be accomplished during final design. Woody material created during the restoration process should be incorporated into the streambed for a dual purpose of habitat and grade control. Wood is already playing a key role to this regard.

Wetland Borrow-

In order to create the earthen fill for the raise grade scenario several borrow areas areas are proposed along the restoration corridor. The size, shape and depth of the proposed borrow areas will ultimately be determined by the amount of earthen fill needed. The final function of these areas would be wetland depressions within the larger wetland system and could resemble historic meanders scrolls or oxbows. Functionally, wetland areas should not exceed a water depth of 1.5 ft depth and have slope greater than a 3:1. Topsoil will need to be stripped and stockpiled temporarily to gain access to the underlying clay material for the streambed subgrade. Stockpiled topsoil will have an existing seed bed to help with restoration. The ultimate goal of

the wetland borrow areas is to produce fill material at a location in close proximity to the restoration. Inlet and outlet structures could be designed to assist in the control of water or floodwater interacting with the wetlands.

Grade Control-

At a minimum at least one distinct grade control structure should be installed at the downstream terminus of the project. The location of this structure and its function should serve as a means to convey base flow and storm water flow into the existing channel from the restored section. Due to the elevation difference this could be a significant structure. However, it is recommended that the elevation be carried through a grade control riffle of at least 75ft and attempt to maintain a slope 4% or less. Therefore this structure would appear as a long steep riffle composed of large boulders and wood. It is also recommended that the grade control riffle structure be keyed into both stream banks at a determined distance to convey storm water flows from the new floodplain into the existing channel alignment downstream. Hydraulic modeling should be performed to ensure that the structure is carried to appropriate elevations and enough stability is present to handle this convergence of flows. As a potential alternative short floodplain channel could be design on either side of the structure to help convey flows.

Other grade control riffles can be designed into the project to provide additional grade control. It is recommended to use the same riffle approach and to avoid drop structures that distribute elevation difference over a short distance. These other grade control riffles would be designed at a slope appropriate to the typical longitudinal profile (i.e. normal riffle slope)

Access Road-

A construction access road is proposed along the western portion of the project. The access road will be approximately 15 ft in width and require the removal of vegetation. The end alignment of the road is variable and can be shifted to avoid sensitive communities are perennially wet areas. Moist or wet areas should be bridged with timber mats to facilitate reclamation of existing topography. A construction access road is necessary for the project to effectively transport fill material and imported material. Following the project the road should be decompacted with a tiller attachment or ripped to a depth that effectively removes compaction. The dense wetland community will greatly aid in the natural reclamation of the area in addition to native seed and plantings.

Bessie Benner Metzenbaum Park Restoration Cost Estimate

Task	Estimated Cost
Permitting	$9,700.00
Design	$39,494.18
Construction	168,154.24
Oversight	$14,100.00
Plants	$29,316.67
Totals	**$260,765.08**

APPENDIX B

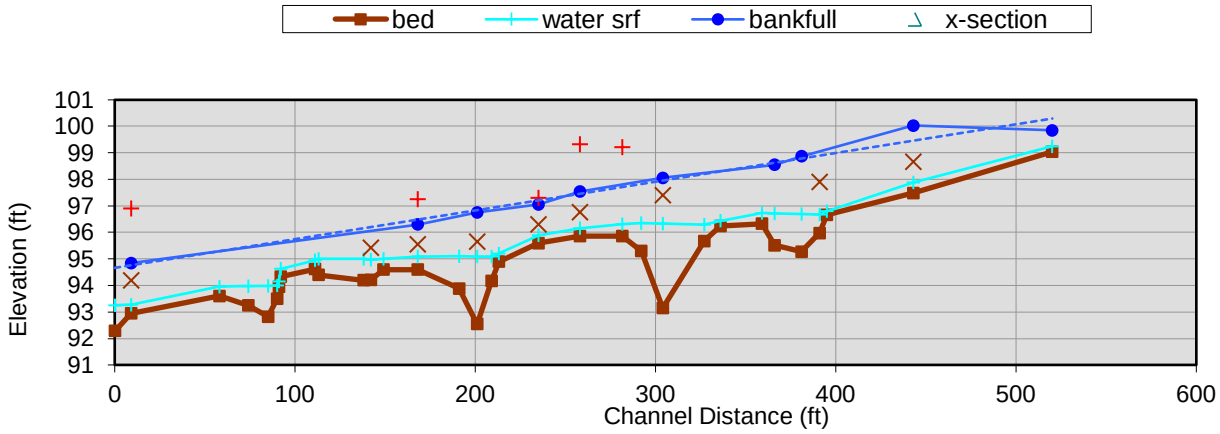
Stream Characteristics at 6 Parcels

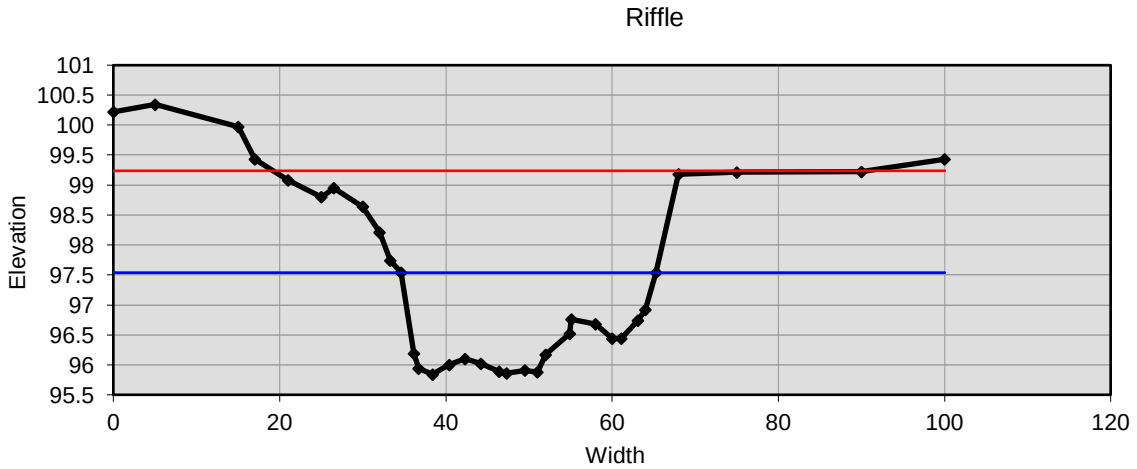
Parcel #	Drainage Area (mi^2)	Stream Type	Bankfull Width (ft)	Erosion Rating
11-711400	1.5	E5	12	Very High
26-707033	3	C4	30	High
26-003310	5.4	C4/3	32	Extreme
26-028780	6.5	C3	42.6	Extreme
88225008	7.2	C1	31	Low
88223006	7.2	C3		Extreme

APPENDIX C

Reference Reach Survey Data (Laurel School stable reach)

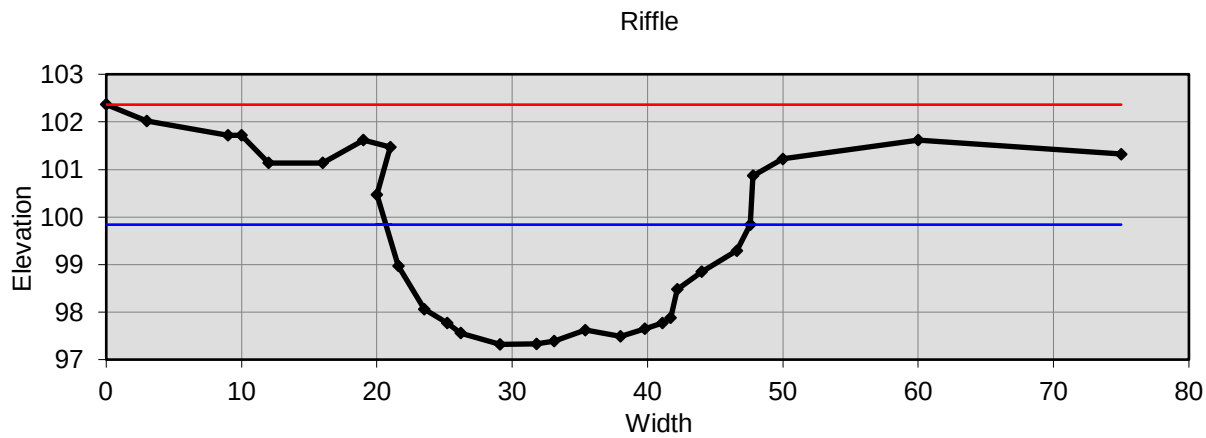
The stream reach at Laurel School, Butler Campus on Fairmount Road was noted as a fairly stable reference reach for Griswold Creek. Longitudinal profile, cross-section, and pebble count data are presented below. Contact CRWP for additional survey data.





Bankfull Dimensions	
38.3	x-section area (ft.sq.)
30.7	width (ft)
1.2	mean depth (ft)
1.7	max depth (ft)
31.6	wetted perimeter (ft)
1.2	hydraulic radius (ft)
24.6	width-depth ratio

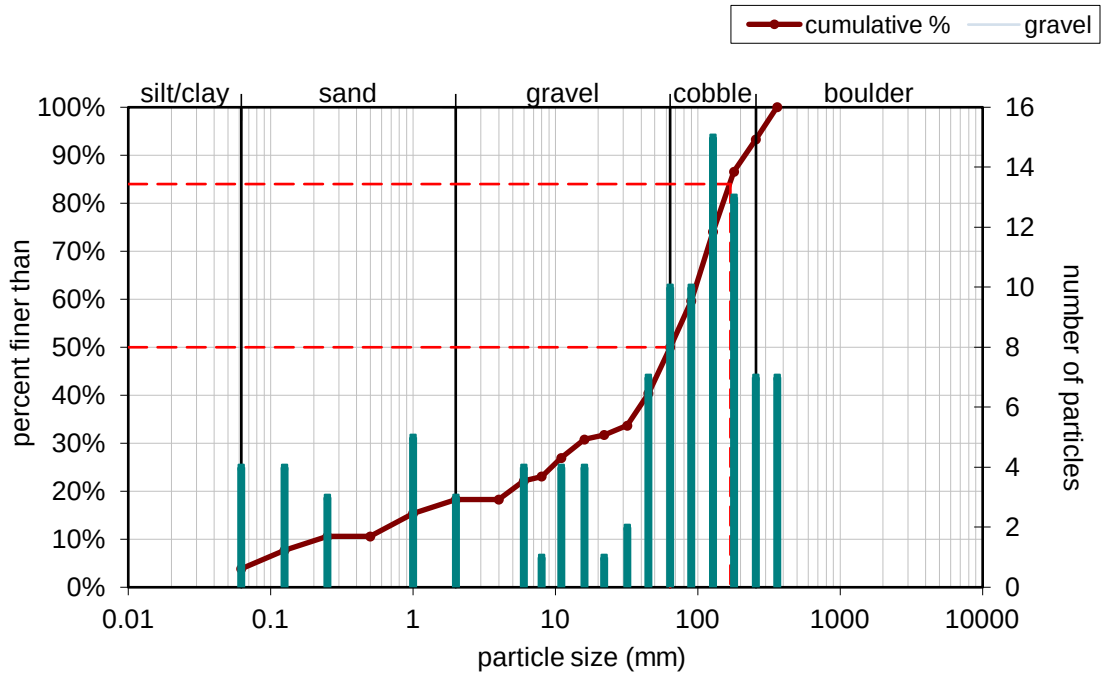
Flood Dimensions	
71.8	W flood prone area (ft)
2.3	entrenchment ratio



Bankfull Dimensions	
49.9	x-section area (ft.sq.)
26.9	width (ft)
1.9	mean depth (ft)
2.5	max depth (ft)
28.1	wetted perimeter (ft)
1.8	hydraulic radius (ft)
14.5	width-depth ratio

Flood Dimensions	
100.0	W flood prone area (ft)
3.7	entrenchment ratio

Riffle Surface Pebble Count, ---



Size (mm)	
D16	1.2
D35	34
D50	64
D65	100
D84	170
D95	280

Size Distribution	
mean	14.3
dispersion	28.0
skewness	-0.44

Type	
silt/clay	4%
sand	14%
gravel	32%
cobble	43%
boulder	7%

APPENDIX D

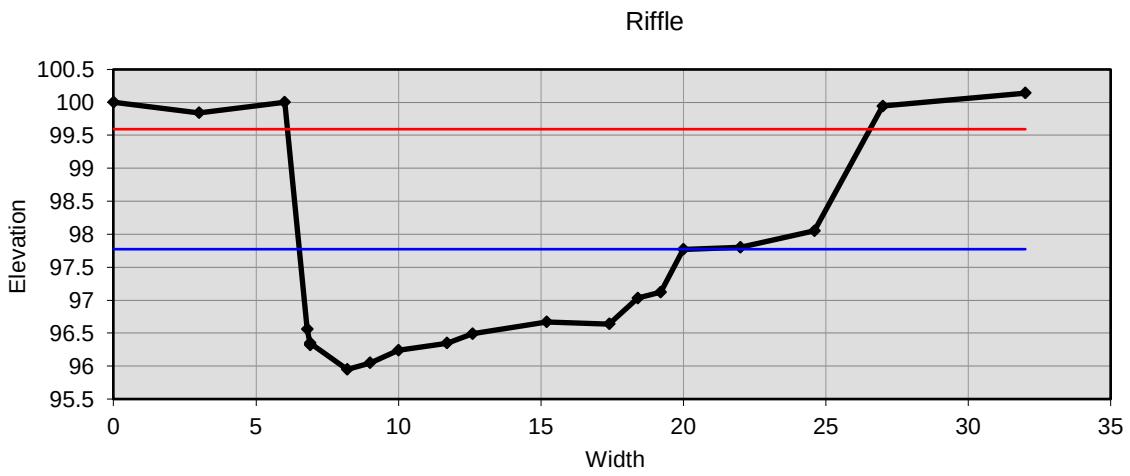
Impaired Reach Survey Data

Stream surveys were conducted at five sites (from upstream to downstream):

1. Valley View WWTP
2. Geauga Park District's Bessie Benner Metzenbaum Park
3. Davis Dam
4. The Club at Hillbrook
5. Bowen Dam Site

Details of the channel dimensions for each of these sites are summarized below. Contact CRWP for additional survey data.

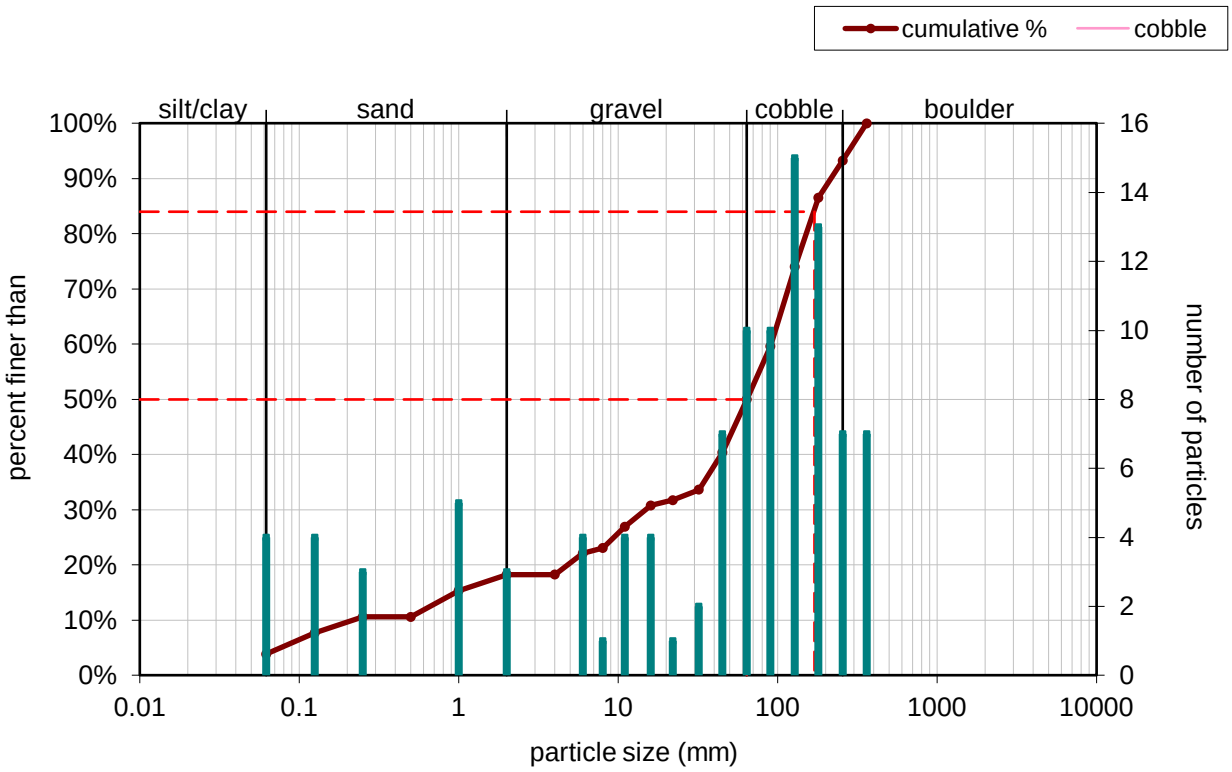
Valley View WWTP



Bankfull Dimensions	
16.5	x-section area (ft.sq.)
13.5	width (ft)
1.2	mean depth (ft)
1.8	max depth (ft)
15.0	wetted perimeter (ft)
1.1	hydraulic radius (ft)
11.0	width-depth ratio

Flood Dimensions	
20.5	W flood prone area (ft)
1.5	entrenchment ratio

Riffle Surface Pebble Count, ---

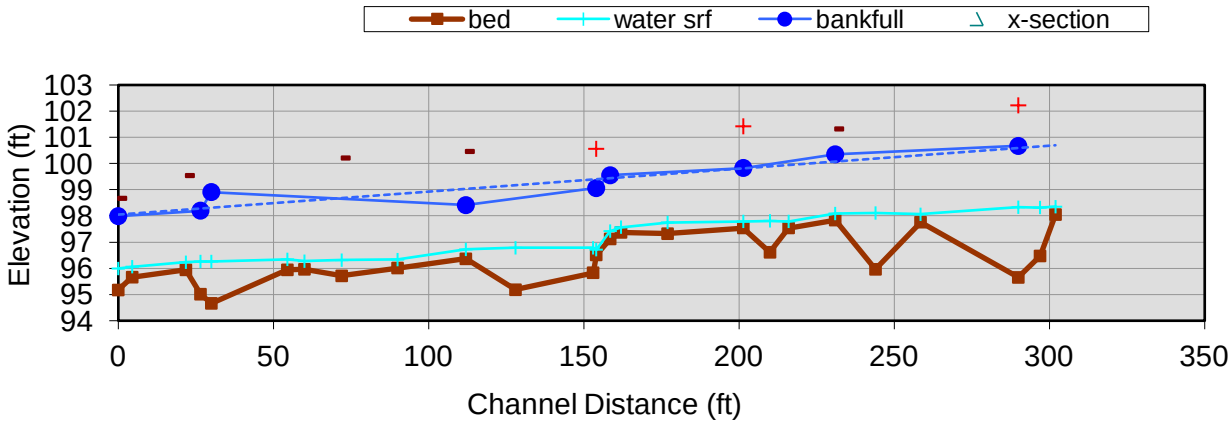


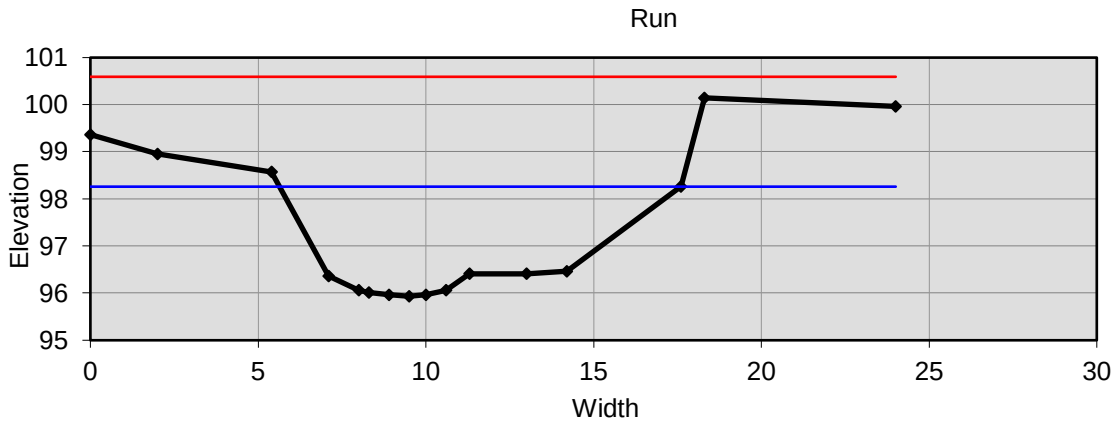
Size (mm)	
D16	1.2
D35	34
D50	64
D65	100
D84	170
D95	280

Size Distribution	
mean	14.3
dispersion	28.0
skewness	-0.44

Type	
silt/clay	4%
sand	14%
gravel	32%
cobble	43%
boulder	7%

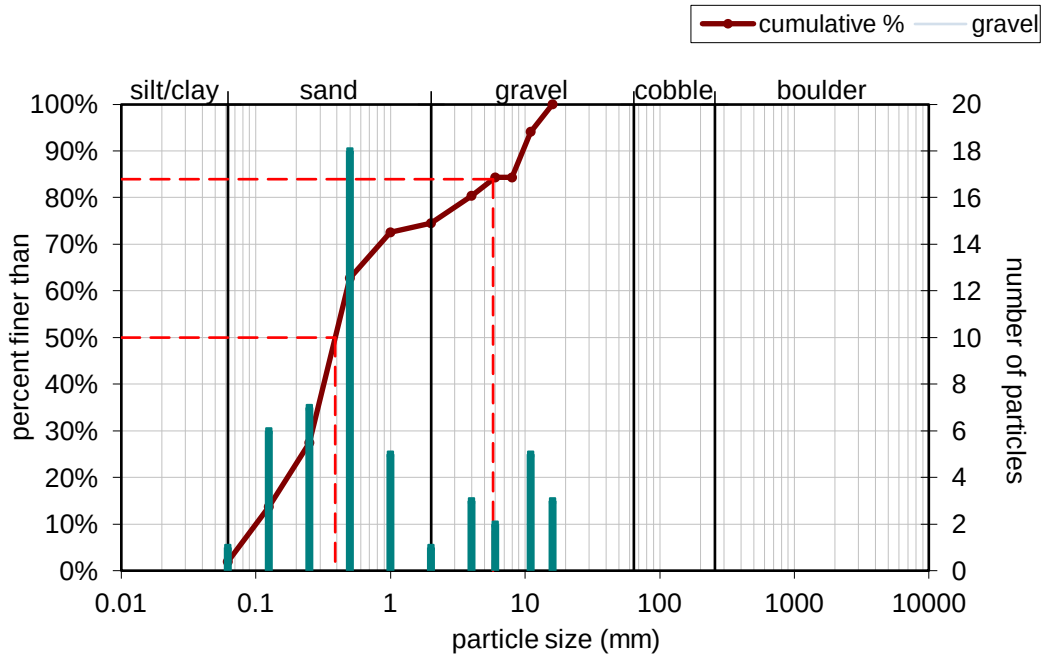
Geauga Park District's Bessie Benner Metzenbaum Park





Bankfull Dimensions	
19.0	x-section area (ft.sq.)
12.0	width (ft)
1.6	mean depth (ft)
2.3	max depth (ft)
13.5	wetted perimeter (ft)
1.4	hydraulic radius (ft)
7.5	width-depth ratio

Riffle Surface Pebble Count, ---

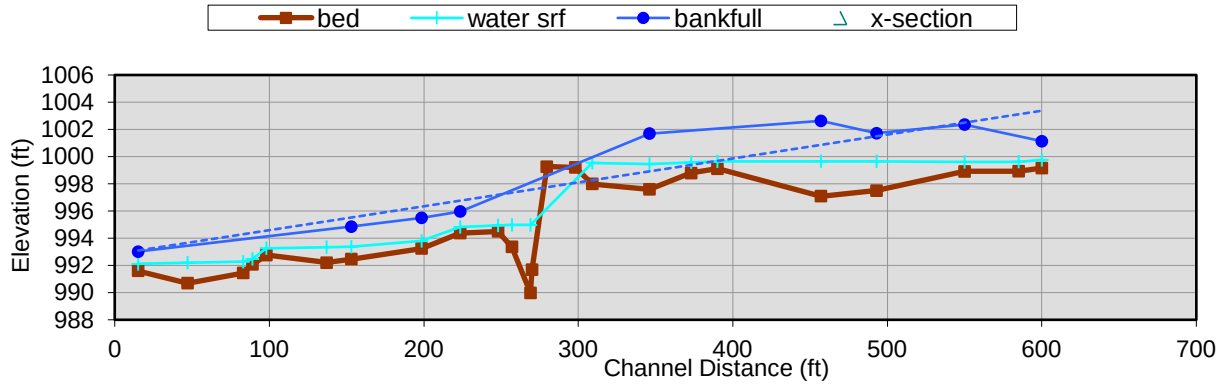


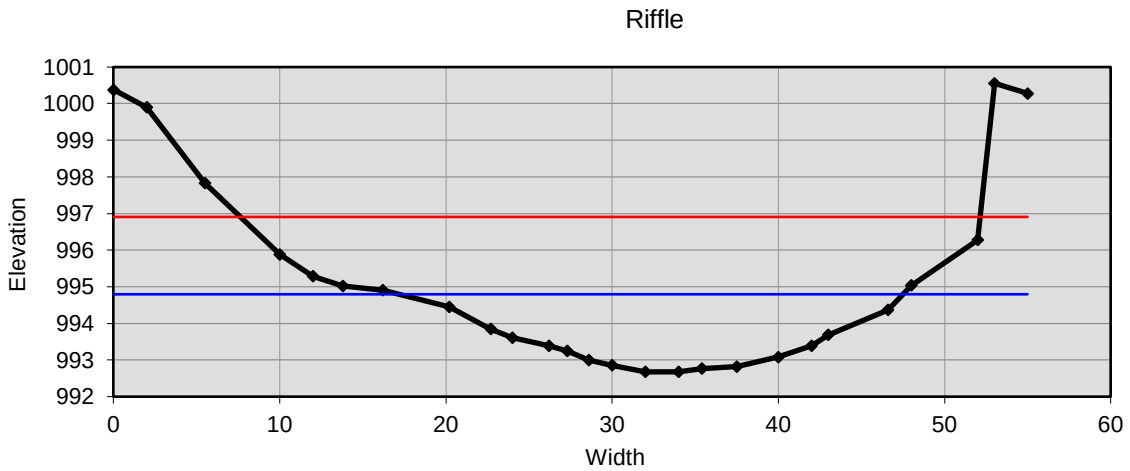
Size (mm)	
D16	0.14
D35	0.29
D50	0.39
D65	0.59
D84	5.8
D95	12

Size Distribution	
mean	0.9
dispersion	8.8
skewness	0.29

Type			
silt/clay	1%		
sand	55%	hardpan	24%
gravel	19%		
cobble	0%		
boulder	0%		

Davis Dam

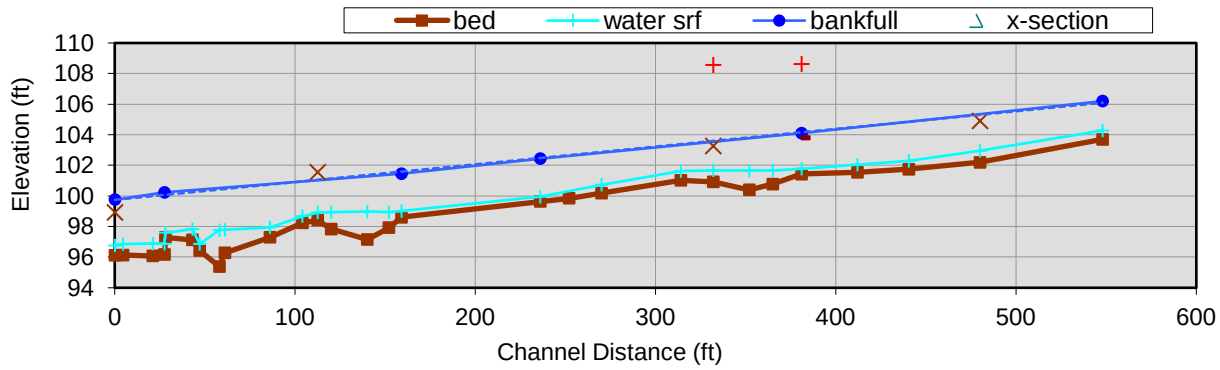


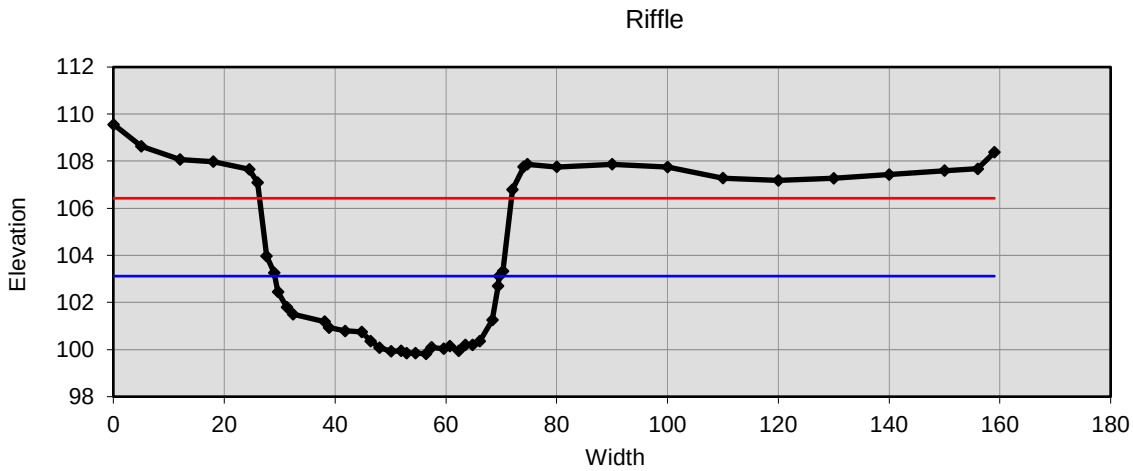


Bankfull Dimensions	
39.9	x-section area (ft.sq.)
30.2	width (ft)
1.3	mean depth (ft)
2.1	max depth (ft)
30.6	wetted perimeter (ft)
1.3	hydraulic radius (ft)
22.9	width-depth ratio

Flood Dimensions	
44.5	W flood prone area (ft)
1.5	entrenchment ratio

The Club at Hillbrook

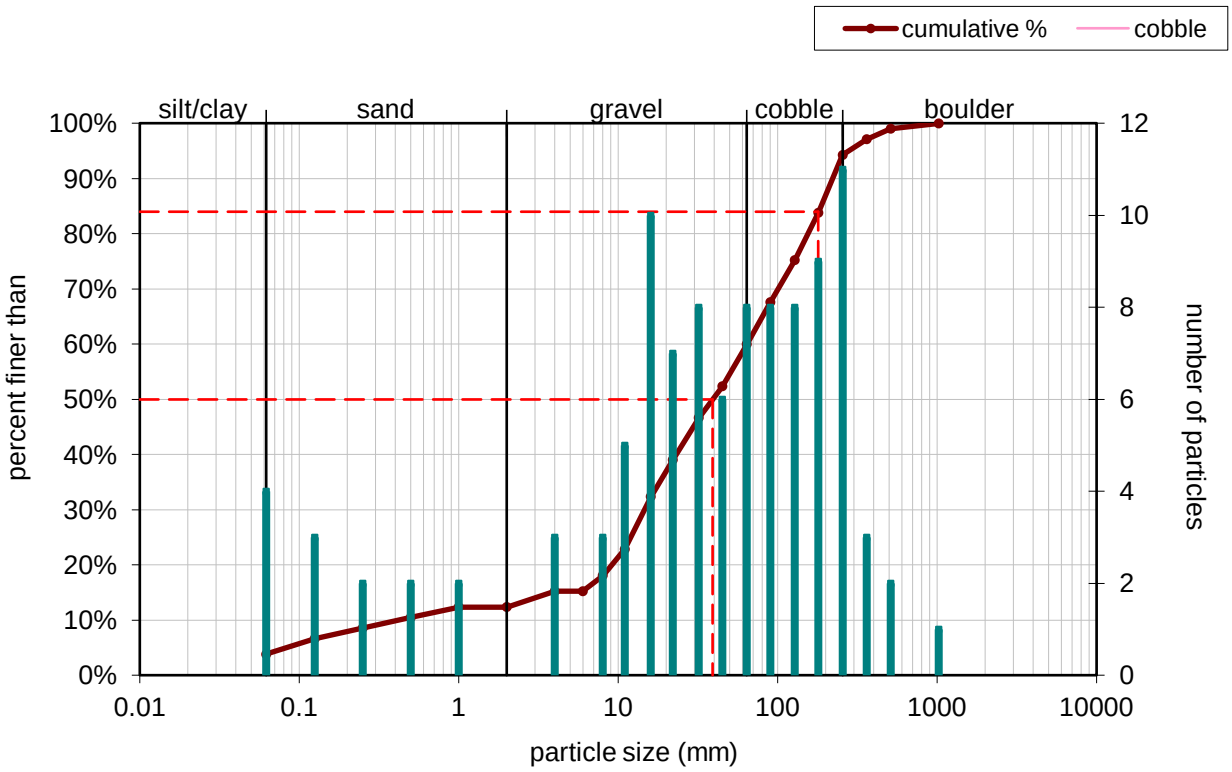




Bankfull Dimensions	
100.2	x-section area (ft.sq.)
40.5	width (ft)
2.5	mean depth (ft)
3.3	max depth (ft)
42.4	wetted perimeter (ft)
2.4	hydraulic radius (ft)
16.3	width-depth ratio

Flood Dimensions	
45.5	W flood prone area (ft)
1.1	entrenchment ratio

Riffle Surface Pebble Count, ---

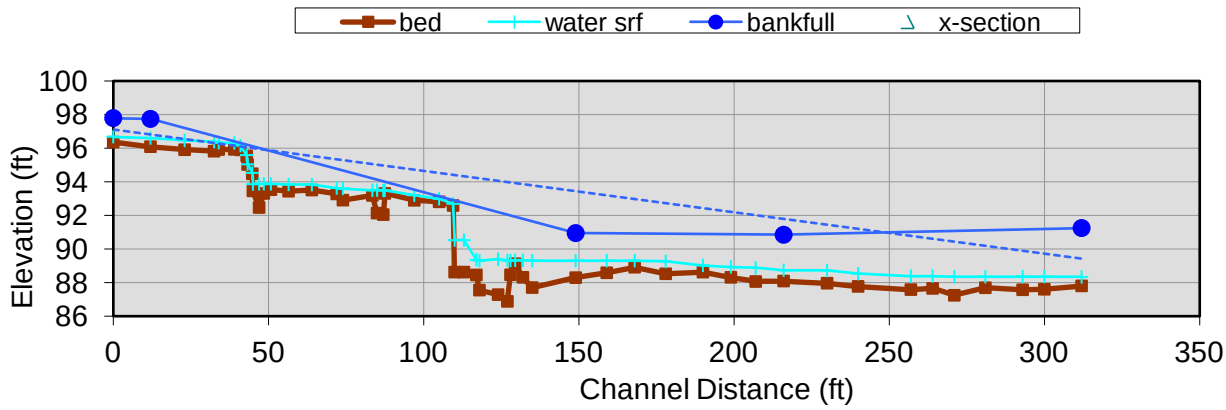


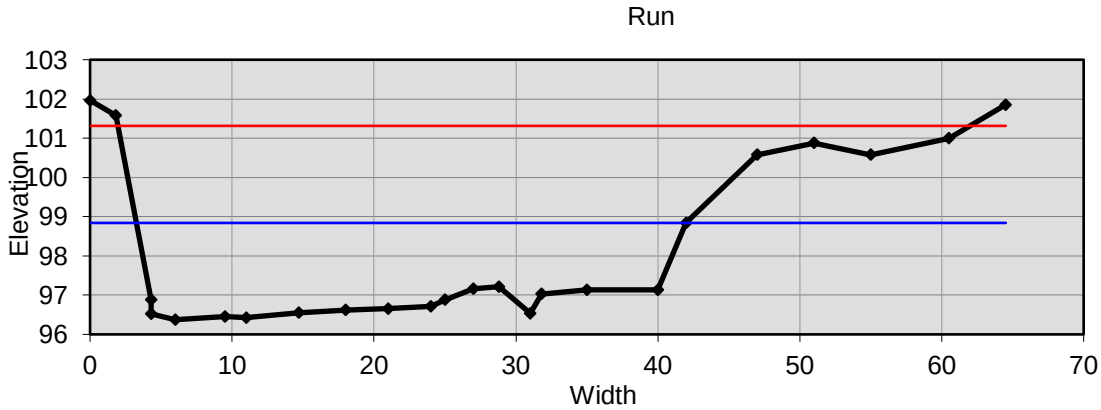
Size (mm)	
D16	6.5
D35	18
D50	39
D65	80
D84	180
D95	280

Size Distribution	
mean	34.2
dispersion	5.3
skewness	-0.05

Type	
silt/clay	4%
sand	9%
gravel	48%
cobble	34%
boulder	6%

Bowen Dam

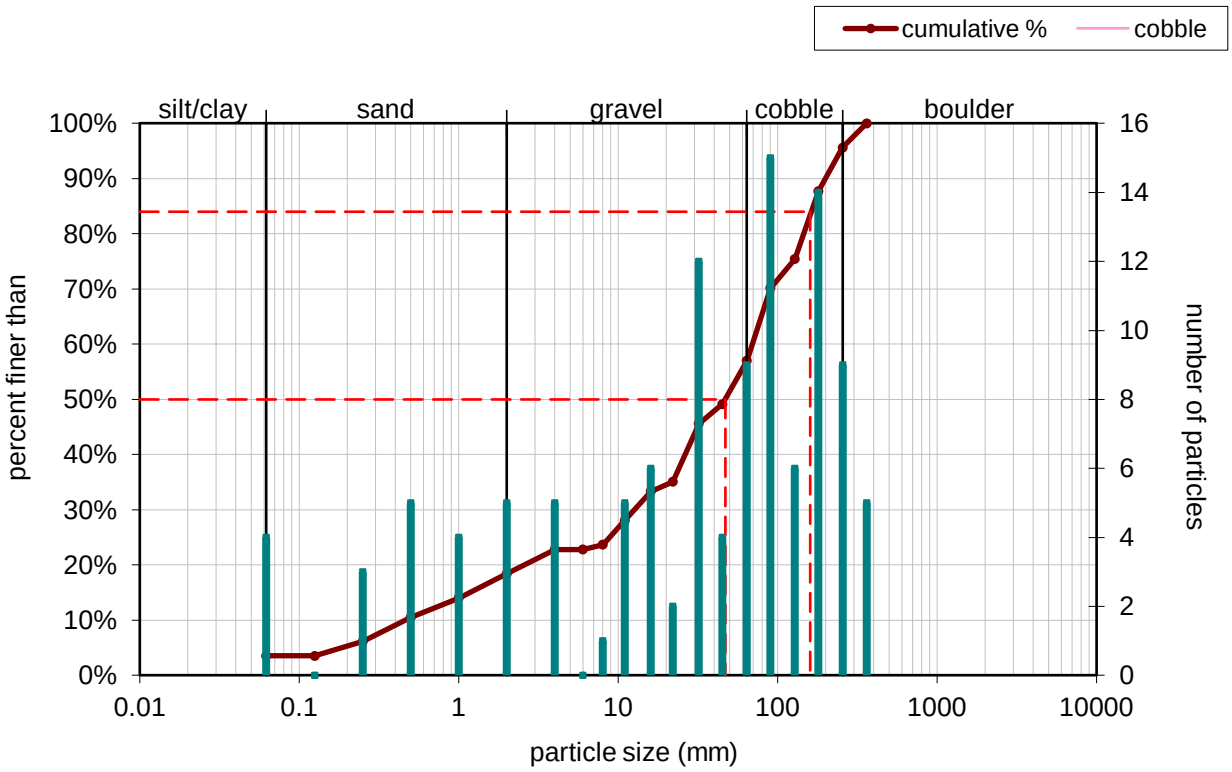




Bankfull Dimensions	
75.3	x-section area (ft.sq.)
36.7	width (ft)
2.0	mean depth (ft)
2.5	max depth (ft)
38.6	wetted perimeter (ft)
2.0	hydraulic radius (ft)
17.9	width-depth ratio

Flood Dimensions	
60.0	W flood prone area (ft)
1.6	entrenchment ratio

Riffle Surface Pebble Count, ---



Size (mm)	
D16	1.4
D35	22
D50	47
D65	79
D84	160
D95	250

Size Distribution	
mean	15.0
dispersion	18.5
skewness	-0.35

Type	
silt/clay	4%
sand	15%
gravel	39%
cobble	39%
boulder	4%