ABSTRACT

Title of Thesis: REGENERATIVE STORMWATER CONVEYANCE: TECHNIQUES TO WATERSHED STEWARDSHIP & TURNING STORMWATER LIABILITIES INTO AMENITIES

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Regenerative Stormwater Conveyance (RSC) is a moderately new best management practice primarily implemented in the mid-Atlantic region. This thesis documents the proposed design of an RSC at Parkdale High School in the Washington D.C. metropolitan region. A degraded channel with incised banks between 9 to 12 feet in height was found on site. This stormwater channel runs for 160 feet and has a contributing catchment of 17.2 acres.

The proposed RSC was designed to stabilize the channel banks, and create a stable channel profile. The runoff storage volume was calculated to be 4523.1 ft^3 total which would treat a runoff volume of 0.24”. This equates to 32% TN, 37% TP and 40% TSS removal. The design provides a viewing area with a photo point and bank pin that would provide an opportunity for students and teachers to assist in visually documenting sediment deposition and geomorphological changes that may occur.

REGENERATIVE STORMWATER CONVEYANCE: TECHNIQUES TO WATERSHED STEWARDSHIP & TURNING STORMWATER LIABILITIES INTO AMENITIES

by

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Lastly, to my parents and extended friends, particularly Chloe Harrell and my mother for help carrying the load.

"Remember, I'm pulling for you; we're all in this together."

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CHAPTER 1: RESEARCH OVERVIEW

Introduction

Regenerative stormwater conveyance (RSC) is a relatively new stormwater treatment and control retrofit which consists of a set of pools, cobble and boulder riffles and cascades (see figure 1.1). It utilizes a sand/mulch media substrate to treat and detain stormwater, and is often an on-line practice implemented within existing ephemeral and headwater channels. RSC is also referred to as regenerative step pool stormwater conveyances (SPSC) (Flores, et al., 2012; MDE, 2014), seepage wetlands (Browning, 2010), regenerative *stream* conveyances, base flow channel design and coastal plain outfalls (WQGIT, 2014; Flores, et al., 2012). RSCs have been implemented throughout Maryland and Washington DC for over a decade. However, there is a scarcity of information available concerning their nutrient and sediment

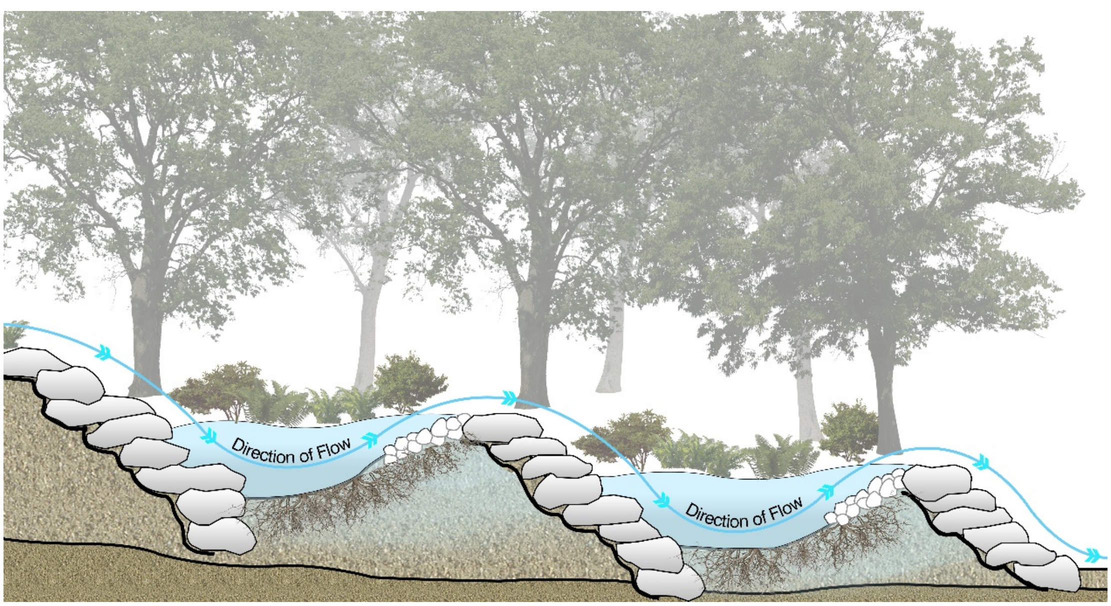


Figure 1.1: A typical profile section of an RSC

reduction capabilities and sustainability (Palmer et al., 2014; Browning, 2010; Williams et al., 2016), particularly outside of the coastal plain physiographic region.

Figure 1.2: Atlantic white cedar at the native planting exhibit at the National Botanical Garden

Initial installations of RSC in the United States were almost exclusively in the coastal plain in Anne Arundel County, Maryland in the early 2000s (Underwood, et al., 2005; Browning, 2010; Brown, et al., 2010; Filoso and Palmer, 2009). These early place-specific implementations of RSC often also focused on the creation of habitat for the globally rare and endangered, Atlantic white cedar (*Chamaecyparis thyoides*), in addition to improvement of stormwater management and water quality (Underwood et al., 2005; Browning, 2010). Prior to the creation of the Howards Branch project in Anne Arundel County, MD; only 10 known stands of Atlantic white cedar remained on the western shore of Maryland (Underwood, et al., 2005). However, as of December, 2016 Atlantic white cedar is considered “apparently secure” globally, and, within the state of Maryland, Atlantic white cedar is considered “vulnerable” (MD NHP, 2016).

Over the past sixteen years, implementation of RSC has expanded from use in the coastal plain westward into the fall-line and piedmont physiographic regions in

Maryland and Washington D.C. It has also been utilized in Virginia, Pennsylvania (US NPS, 2011), West Virginia and North Carolina, having slightly differing components in the latter. RSC is now a credited stormwater best management practice BMP by the Maryland Department of the Environment (MDE, 2014) and the EPA Chesapeake Bay Program (WQGIT, 2014 Hayes, 2016).

Watershed Management Challenges

As seen in figure 1.3 Maryland has been continually developing since the mid-twentieth century; and with this increase in development has come greater stormwater management challenges in the watersheds from increasingly more impervious area. This increase in development has led to larger stormwater flows with more erosive force. In the future Maryland's population, (see table 1.1) density and impervious coverage (see figure

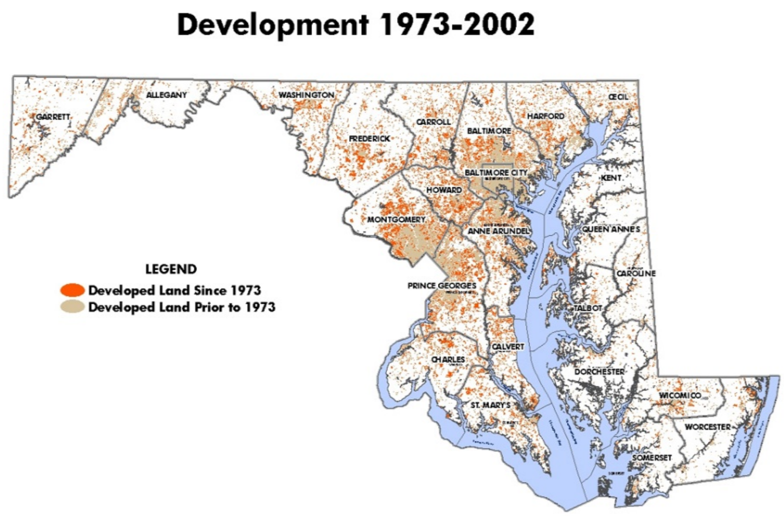


Figure 1.3: Development in Maryland from 1973-2002. (Maryland Department of Planning, 2005)

	Census 1970	Census 2000	Projection 2030
Frederick Co.	24,926	70,060	122,025
Montgomery Co.	156,674	324,565	420,000
Prince George's Co.	**192,963**	**286,610**	**367,700**
Baltimore Region	623,868	958,756	1,164,375
Washington Suburban Region	374,563	681,235	909,725
Maryland	**1,174,933**	**1,980,859**	**2,555,775**

Table 1.1: Census and Projected Households in Maryland and its jurisdictions (Maryland Department of Planning, 2005)

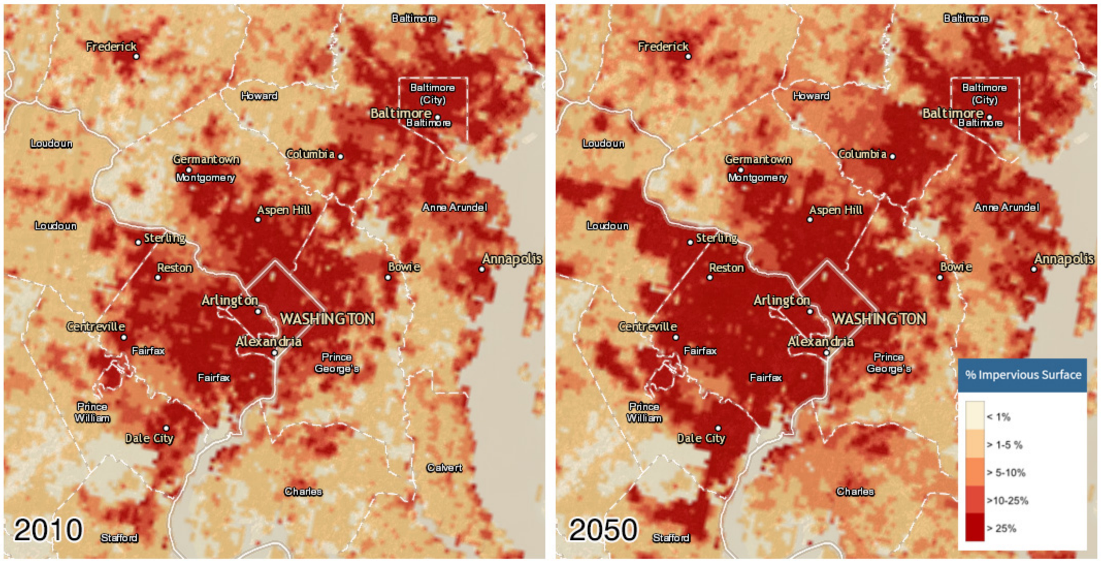


Figure 1.4: A set of maps which display expected increase in impervious surface coverage in the Washington D.C. metropolitan area over the next three decades (EPA, 2017)

1.4) are expected to continue to increase, which will create even greater stress on already stressed stormwater channels and streams at every level of watershed within the Chesapeake Bay Watershed. This is exacerbated by climate change projections which indicate that there will also be an increased frequency of larger-volume storms that will further increase stormflow runoff by 10% to 20% from urban areas, and increase pollutant loads (Williams et al., 2017).

Insufficient design techniques and improper stormwater management has led to several challenges in watershed headwaters, and in the receiving channels and

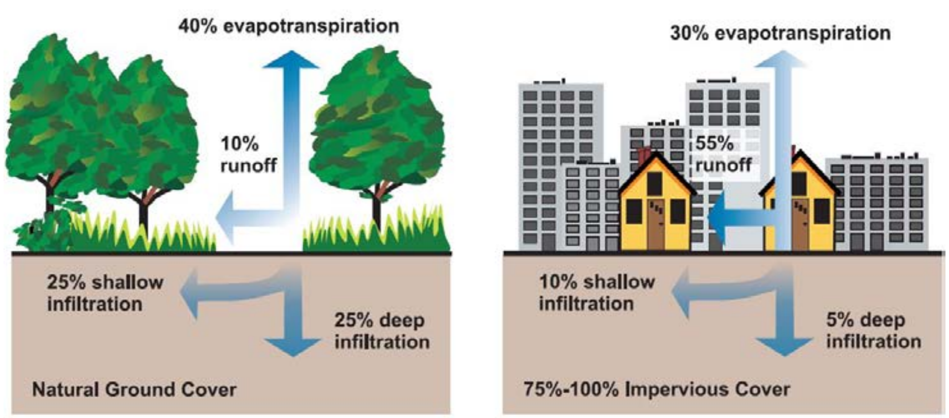


Figure 1.5: A diagram of the changes to runoff and the natural water cycle between an area of natural ground cover and a highly urban environment. (EPA, 2006)

streams, such as greatly increased runoff volumes and peak flows as diagramed in figure 1.5 (US EPA, 2013; MDE, 2009). As a result of large peak flows and runoff volumes deep channel and stream incision like that pictured in (figure 1.6) has become common. In addition to channel degradation, stormwater quality is diminished due to increased pollutant loading, overabundance of nutrients and sediment which collect in receiving water bodies (Berg, Underwood, 2009; Palmer et al., 2014). The result of decreased water quality is negative effects such as habitat degradation (WQGIT, 2014), reduction in stream navigability and recreational and commercial fishing decreases (Filoso and Palmer 2009; Brown et al., 2010).

Figure 1.6: A deeply incised stream channel at Greenbelt Park in the Washington D.C. Metropolitan

The channel design technique, RSC, is a product of the realized necessity to manage stormwater and respond to the problems and challenges materializing in watersheds. RSC is part of the post-EPA Clean Water Act (CWA) Total Maximum Daily Load (TMDL) stormwater management paradigm shift from past industrial techniques (Berg and Underwood, 2009), and other insufficient stormwater management (Williams et al., 2017), as illustrated in figure 1.7.

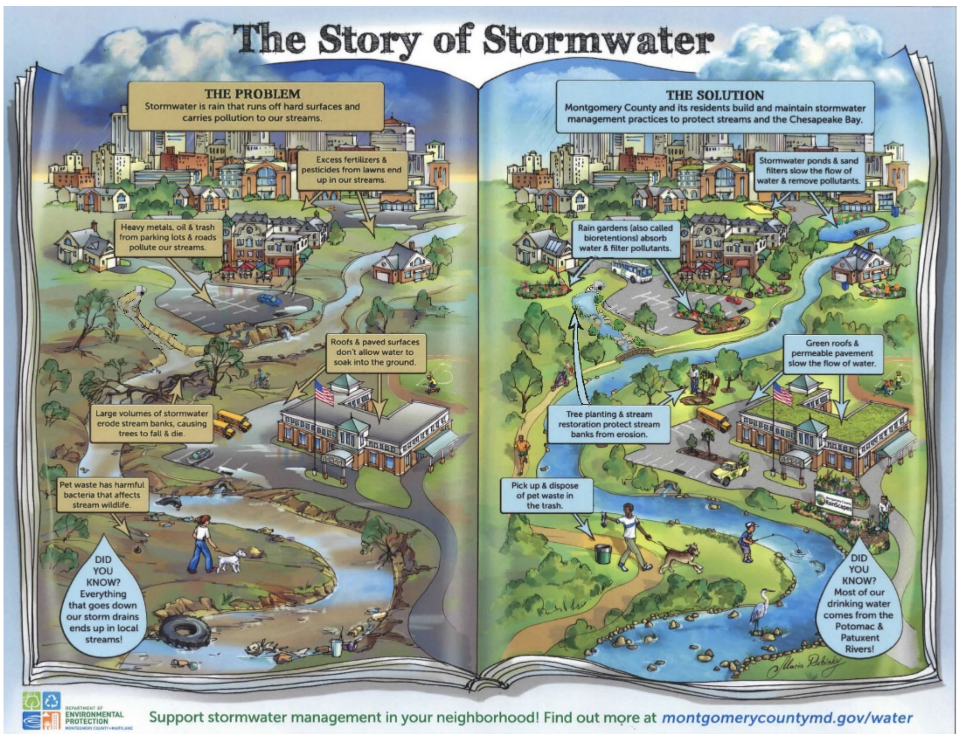


Figure 1.7: Previous stormwater design paradigms and consequences of it; versus the new design paradigm and solutions to problems and stormwater challenges (modified from Montgomery County Department of Environmental Protection)

Benefits of RSC

RSC is attractive, beneficial and economical for dealing with a varied array of development related issues that challenge communities, government officials and planners (See Table 1.2). As asserted by Maura Browning, “Using [RSC] to slow and retain water may even be one of the best options for urban headwater streams”.

Furthermore, RSC has been shown to have cost savings at a ratio of 2:1 or 6:1 when compared to other stream restoration techniques (Brown et al., 2012).

Benefits of Regenerative Stormwater Conveyances		
Environmental		
	Water Quality	• Pollutant adsorption, excess nutrient uptake • Potential water recharge • Peak Flow reduction • Channel Protection
	Habitat Creation & Preservation	• Low disturbance area • Instream habitat improvement • Increased habitat diversity
Social		
	Educational & Recreational	• Can be used for teaching and research • Aesthetically valuable
Economical		
	Maintenance Cost	• 100-year storm resilience • Self-sustaining/ regenerative
	Construction Cost	• Savings between 2:1 to 6:1 relative to stream restoration
	Liability Reduction	• Lessens falling hazards

Table 1.2: The benefits of regenerative stormwater conveyances

Limitations and the State of Research

While RSC is attractive for dealing with many stormwater challenges; RSC is still in a seminal phase of understanding and implementation around the nation (Filoso Palmer, 2009; Koryto, 2016; Brown et al., 2010). Stream restoration as a field needs more integrated monitoring and research as a whole (Williams et al., 2017); particularly because of discrepancies in research from physiographical region to region that are becoming prevalent within the field of stream and channel restoration as a whole (Filoso & Palmer, 2009). RSC projects in the piedmont and fall-line physiographic areas of Maryland vary in their soil substrates and connection to the water table from those common to the coastal plain physiographic regions, which dominate Anne Arundel County. These differing soil substrates have varying properties and performance (e.g. hydraulic conductivity). Also of concern in the efficacy of RSC techniques outside of the coastal plain is that the angle of repose of soils and ravine slopes of headwaters and first order streams within the piedmont generally have greater in-stream slopes leading to ephemeral streams with greater velocities and less connectivity to the floodplain (May, 2016).

Considering the limited implementation of RSC alone and the very recent proliferation of the technique outside of its physiographic region of origin; this is suggestive that there is likely to be some uncertainties within the field and within communities particularly concerned with if the results can be generalized to other physiographic areas of the Mid-Atlantic. This is exacerbated by the lack of Peer-reviewed studies addressing the performance of RSCs regardless of physiographic region (Williams, et al., 2016). Regardless, the old system of stormwater conveyances in the DC metropolitan area and beyond are aging and degrading and the old system has been found to degrade the health of the watershed at every level (US EPA, 2003).

CHAPTER 2: LITERATURE REVIEW

The Clean Water Act and Increasingly Stringent Storm Water Management Permitting

The EPA, under the CWA, have implemented regulations that have repercussions related to the use of RSC as a design strategy and as a stormwater BMP. These programs regulate discharge of TMDLs, particularly nutrients and sediment loads from watershed discharge points. In 2010, the EPA completed a TMDL for Chesapeake Bay that identifies total nitrogen (TN), total phosphorous (TP) and total suspended solids (TSS) load reductions needed to meet water quality standards (Williams et al, 2017). Respectively, the prescribed reductions are 25%, 24% and 20% by the year 2025 (US EPA, 2010).

The National Pollution Discharge Elimination System (NPDES) defines a Municipal Separate Storm Sewer System (MS4) as a conveyance system (or series of systems) including roads with drainage systems, municipal streets, catch basins, curb, gutters, ditches, manmade channels, or storm drains that are owned and operated by the county or a city, town, association, or public body. MS4 permits require MS4 jurisdictions to perform watershed assessments and develop restoration plans in order to meet stormwater wasteload allocations (WLAs) (MDE, 2014). MS4 permits establish two specific requirements for developing restoration plans in Maryland. The first involves restoration of 20% of a jurisdiction’s impervious surface area that has little or no stormwater management. The impervious area restoration requirement is part of the strategy in Maryland’s Watershed Implementation Plan (WIP) for meeting the Chesapeake Bay TMDL (MDE, 2014). Furthermore, as part of the interim goal achievements, strategies responsible for an estimated 60% of the TMDL goals are to be implemented in 2017, and total implementation is expected by 2025 (Williams et al., 2017; US EPA 2010).

The county of Prince George's county was issued a MS4 permit in January 2014 which required the development of local restoration plans for each approved TMDL by January of 2015 (PGC DoE, 2014). This led to the creation of plans for five major watersheds. The plan most relevant for the research and design undertaken in this thesis is that of the Anacostia River watershed.

How RSC Works

The sand seepage bed, with its 20%-by-volume green mulch, supports microbes, fungi, macroinvertebrates, and processes which remove nutrients and contaminants as they pass through the sand bed (Brown et al., 2010; May, 2016). Furthermore, roots present in the soil media from planted and naturally occurring vegetation support maintenance of porosity as well as take up nutrients and provide sites for microbial attachment, contaminant adsorption, and long-term sequestration in the peat forming layer resulting from annual root formation (Brown et al., 2010). Step pool sequences in RSCs decrease nitrogen loads, because they "increase topographic complexity, surface-to-area-volume ratio, and hydraulic retention to allow for greater contact between the water and the benthos (e.g., introduction of large, woody debris, construction of pool-riffle or step-pool sequences) (Browning, 2010)."

The detention and slow release of seepage is intended to restore the baseflow regime of the receiving stream by mimicking predevelopment shallow inter-flow

(Brown et al., 2010; Cizek and Hunt, 2013). The seepage beds and pools of RSCs also have the potential to increase both surface detention storage and the infiltration of runoff (Flores et al., 2009) while improving water quality (Cizek, 2014; Palmer, Filoso, & Fanelli, 2014). When designed and constructed properly RSCs have been shown to "regenerate" and be mostly self-sustaining (Brown et al., 2010)

RSC, Magnolia Bogs and Biomimicry

RSC has its roots in innovation from existing naturally occurring ecosystems in nature. These naturally occurring ecosystems are the *coastal plain acidic seepage swamp*, *the fall line terrace gravel bog*, *magnolia bogs*, and finally the *instream beaver dam* (Hayes, 2016; Simmons and Strong, 2003). The first three, nearly synonymous, ecosystems mentioned above are landscapes that are fed by groundwater that seeps through highly permeable layers of sand and gravel and consist of a series of repeated shallow pools and mounds, or hummocks (Harrison and Knapp, 2010). Beaver dams result in sequences of dams and resulting impoundments that modulate stream flow, act as sediment sinks, connect a stream to its floodplain, and create a greater diversity of stream habitats (Butler and Malanson, 2005; Wright, Jones, and Flecker, 2002; Hayes, 2016; Berg 2009).

There are 13 known remaining Magnolia Bogs of the fall-line vicinity in Maryland, D.C., and Virginia (Marilandica: Journal of the Maryland Plant Society, 2003; National Parks Service, 2007). These bogs all occur between the cities of Laurel, MD and Fredericksburg, VA. Peatlands, pocosins, fens and bogs are

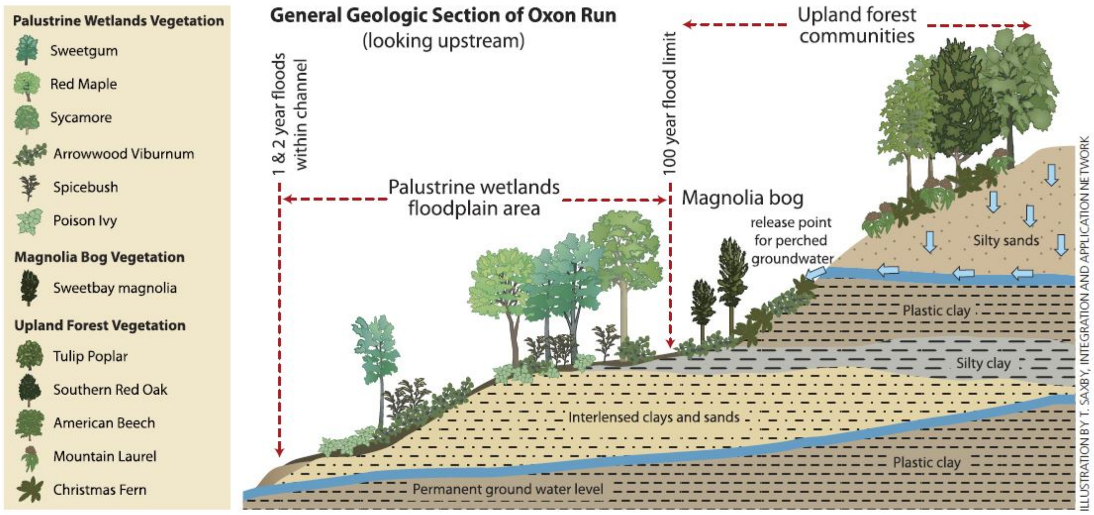


Figure 2.1: An example of magnolia bog geological, hydrological and ecological location (NPS, 2007)

extremely rare in the coastal plain due to development; magnolia bogs in particular are very rare and many of those bogs that were initially surveyed have been destroyed (Simmons and Strong, 2003).

Magnolia bogs are closely associated with terrace gravel forests, and only occur below sandy gravel terraces of substrate (see figure 2.1) located in the inner mid-Atlantic coastal plain (National Parks Service, 2007). These ecosystems occur in highly acidic soils and are often relatively small in area; usually encompassing less than an acre of contiguous land (Simmons and Strong, 2003).

Some plants particularly attributed to magnolia bogs are highbush blueberry (*Vaccinium corymbosum*), bog fern (*Thelypteris simulata*), poison sumac (*Toxicodendron vernix*), sphagnum moss (*Sphagnum spp.*) and sweetbay magnolia (*Magnolia virginiana*). The unique assemblage of the ornamental sweetbay magnolias found at these bogs led to these micro ecosystems being accordingly named, “Magnolia Bogs”, in 1918 by W.L. McAtee (National Park Service, 2007; Simmons and Strong, 2003).

RSC Measured Performance in Literature

As stated above RSCs have been claimed to generally improve water quality, remove or take up nutrients and adsorb contaminants, increase infiltration and detention of rehabilitated reaches and restore the baseflow of receiving streams. Most of these claims are substantiated in the literature researched within this paper. All of the statistics below pertain to studies done in the Coastal Plain physiographic region within Anne Arundel County Maryland.

For nutrient removal Total Nitrogen (TN) had been reduced from 20-30% (Filoso, 2012; Filoso & Palmer, 2009). Rates of reduction span from 1kg to 3kg of nitrogen (N) removed per hectare per year (kg ha^{-1} $year^{--1}$) (Filoso, 2009; Williams et al. 2016). The former rate of 1k ha^{-1} $year^{-1}$ was described as "not significant in the effort [to address nitrogen loading]."

Nutrient removal of phosphorous was not reported as rigorously; regardless, one study measured total phosphorous load reductions of 0.94 kg ha^{-1} $year^{-1}$ (Williams et al., 2016), and Filoso had measured total dissolved phosphorous reductions in 90% of measures.

For a broader understanding of water quality: studies by Filoso in 2012 measured Total Suspended Solid (TSS) load reduction of 70% relative to a control stream, and another study measured a reduction of TSS at a rate of 33.6 kg ha^{-1} $year^{-1}$ (Williams et al., 2016).

In regards to volume attenuation and infiltration in Anne Arundel County: one study suggested a 63% reduction in flow as a total or 50,818 ft^3 ha^{-1} $year^{--1}$ (1439m^3 ha^{-1} $year^{--1}$)(Williams et al., 2016). Other studies stated that flow was only measurable in half of the storm events relative to a control stream (Filoso, 2012), and that there was significantly enhanced infiltration of stormwater runoff (Fanelli et al., 2017).

Only one study attempted to measure RSCs ability to “restore baseflow”. The findings of that study were that base flow, “remained low in receiving streams and the RSC did not increase long-term storage” (Fanelli et al. 2017). Thus, if the goal of designers and engineers is to restore baseflow, other BMPs such as retention ponds may be more effective for addressing those watershed goals and challenges.

Crediting of RSC in Maryland

RSC, referred to as regenerative step pool storm conveyances in MDE documents, is classified as an “alternative BMP” (MDE, 2014). Furthermore, RSC is classified as a runoff reduction (RR) practice as explained in the document, “Recommendations of the Expert Panel to Define Removal Rates for Individual Stream Restoration Projects”. This designation ties RSC to a set of nutrient and sediment removal curves which assign how much credit will be allotted for undertaking RSC projects (see figure x.x for an example). This credited percentage of nutrient or sediment removal is assigned regardless of the actual performance

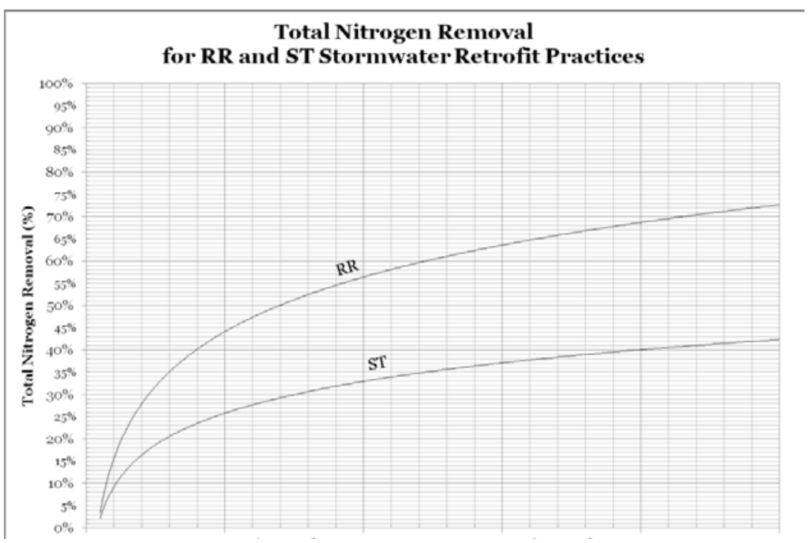


Figure 2.2: A graph which to be used for calculating nitrogen removal rates for BMPs in Maryland based on the calculated runoff depth captured by a BMP. (WQGIT, 2012)

of the RSCs (or BMPs). Credited nutrient and sediment removal rates of RSC in Maryland are, thus, a function of impervious acreage and the stormwater detention volume of the RSC; based on the equation:

$D_r = \frac{(RS)(12)}{IA}$ (WQGIT, 2012)

Where:

RS = The runoff storage volume of the RSC

IA = The impervious area in the targeted catchment

D_r = The calculated depth of stormwater captured for a selected catchment.

CHAPTER 3: PRECEDENT RSC CASE STUDIES

Three precedent designs were chosen to study and illustrate RSC principles and techniques. All exist in the D.C. metropolitan area, and all are located in the piedmont or fall-line physiographic regions. The three implemented RSCs are Briers

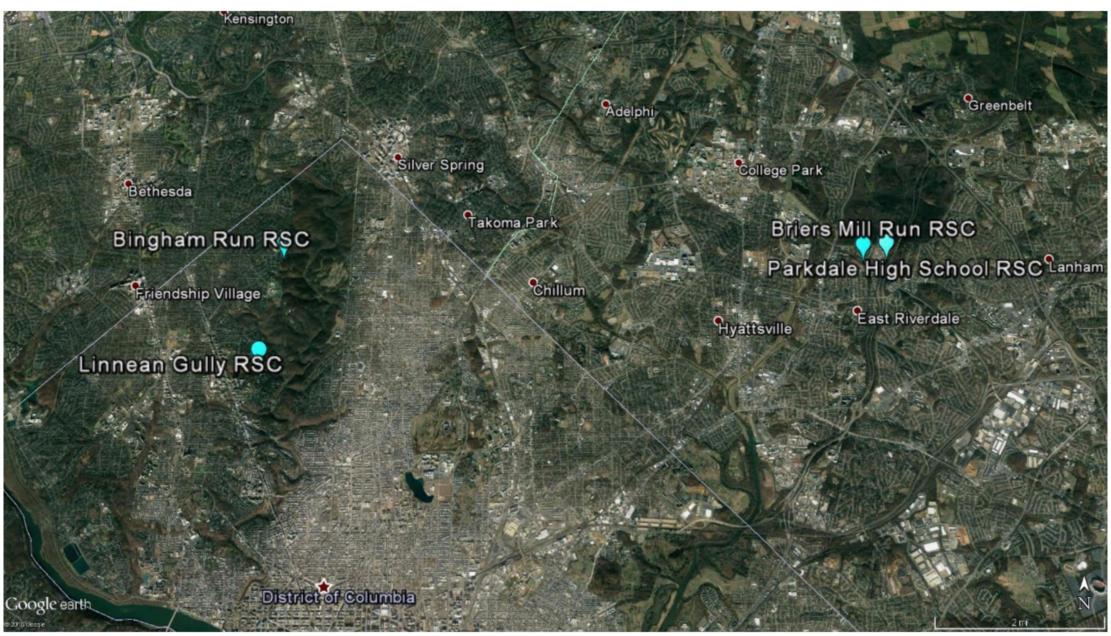


Figure 3.1: Precedent RSC locations and the selected site location (designated by larger font and cyan placemarks)

Mill Run RSC (also known as: William Wirt RSC), Bingham Run RSC, and Linnean Gully RSC (see figure 3.1).

Briers Mill Run RSC

Site Context & RSC Performance

Briers Mill Run RSC is located in Riverdale, Maryland behind William Wirt Middle School downhill of the school and at the far side of the rear soccer field. The RSC was constructed in September 2015 by Underwood & Associates, and was designed by Biohabitats Inc. for the client, Anacostia Watershed Society (AWS). This RSC originates from an outfall pipe 36” in diameter and flows within the conveyance for approximately 132’ before emptying into Briers Mill Run (previously named and known as Briers Mill Ditch).

The RSC treats a watershed of approximately 24 acres. Per the plan-set created by Biohabitats: “[The RSC is] anticipated to treat 87% of the stormwater volume from the watershed using the MDE-Approved step-pool conveyance retrofit

Figure 3.2-3.3: Before (left) and after (right) photographs of the area immediately around the watershed outfall pipe. (Before image used with the permission of Biohabitats)

approach." The disturbance area was 0.42 Acres with 265.1 cubic yards of fill according to the Biohabitats plan-set.

Preconstruction Erosion and Need

The outfall discharges 12' above the receiving stream and over time had created a major gully of similar depth approximately 20 feet wide (Underwood & Associates, 2016) as see in figure 3.2. In addition to the degradation of the receiving channel the initial outfall pipe had degraded and broken apart and the eroded condition of the outfall had little to no stormwater treatment value. The implementation of an RSC at Briers Mill Run was a cost effective method to treat stormwater from the 24 acre catchment at the cost of approximately $350,000 (May, 2016).

Site Design and Site Visits

A series of sand berms, cobble weirs, and step pools were constructed to repair the degraded channel. This regenerative design system allows stormwater runoff to slow down and infiltrate into the landscape, reducing erosive forces and providing time for water quality treatment.

Figure 3.4: Photographs of Briers Mill Run RSC around the pipe outfall immediately after a 2" rain event in summer 2016

During site visits to the Briers Mill Run RSC, one characteristics of the site that stood out was the use of large boulders directly in front of the outfall pipe. This undoubtedly reduces the erosive energy of the water as it flows from the outfall into the stormwater conveyance (see figure 3.4). Other characteristics of the design are utilization of a set of two pools with cobble-boulder riffles in-between the pools and one final extensive run of boulder and cobble. The top most pool was ≈75-100 ft^2 in area and approximately 2' in depth at most. A tree root ball (diameter ≈18") was, curiously, placed upside down about 10' in front of the pipe outfall. Likely this trunk was cut and placed during the construction process. Another larger trunk over 20' in length was placed across the conveyance system (see figure 3.5). During one site visit with high school employees from the Prince George's County 2016 Summer Student

Figure 3.5: A photograph of Briers Mill Run RSC being used for teaching purposes

Youth Employment Program, the youth readily made use of this long downed trunk for seating and as a natural balance beam; while the youth group supervisors talked about stormwater issues related to the design. Similarly the youth frequently scrambled on top of the large placed boulders around the riffle and pool sequences. Near the riffle sequences the sound of the water trickling down the rocks can readily be heard and pleasant mini cascades of water could be viewed.

Site Vegetation

Existing mature canopy trees around the site include several tulip trees, sweet gum trees, red maples (*Acer rubrum*) and various species of oak (*Quercus spp.*). Understory shrubs and trees included boxelder (*Acer negundo*), American hornbeam (*Carpinus caroliniana*), and a few mature pawpaw (*Asimina triloba*) and mountain laurel (*Kalmia latifolia*). Lastly, existing areas or ferns were prevalent around the site in the midsummer.

Figure 3.6: A mature pawpaw tree and Garlic Mustard growing adjacent to the Briers Mill Run RSC.

Figure 3.7: A panoramic photograph showing several species of trees and invasive vines directly uphill of the RSC - along the adjacent soccer field.

The area around the site was relatively free from invasive species except for some invasive vines such as Japanese honeysuckle (*Lonicera japonica*) and the invasive herbaceous plant species garlic mustard (*Alliaria petiolata*).

Figure 3.8: A planted blue flag iris near the RSC

Planted varieties of trees, shrubs, herbaceous plants and grasses are all native and are species that are typically found in the mesic mixed forest and coastal plain floodplains (for specifics on those species: see chapter 4: ecosystem classification). The project planting schedule included 18 native species in total, all classified under the title, “riparian forest”. Some species planted, that seemingly added to the biodiversity of the area are: sassafras (Sassafras albidium), black tupelo (Nyssa sylvatica), American sycamore (Platanus occidentalis), and blue flag iris (Iris spp.).

Problems and Concerns

Between August and September 2017 there was a partial blowout of the Briers Mill Run RSC. The second set of cascades (the one holding back the first pool after the outfall pipe) was blown out on the eastern bank. This blowout diminished the pooling area of the RSC significantly. The first pool is nonexistent and the second pool was largely filled in by cobble and sand infiltration media as depicted in the before-after figure above.

Figure 3.9: Before and after images of the first two sets of weirs and pools downstream of the pipe outfall

The current understanding of what caused this blow out is overland flow of stormwater from the eastern side of the RSC (the left side of the weir in image 3.9), and it was *not* caused by flow from within the RSC channel.

Bingham Run RSC

Site Context and RSC Performance

The Site of the Bingham Run Regenerative Stormwater Conveyance is located completely within the 2,000 acre Rock Creek Park in Northern Washington D.C. The channel flows for ≈600 feet with an average slope of 8-10% before discharging into Bingham Run which flows eastward along Bingham Drive eventually emptying into Rock Creek (see figure 3.10). The implemented RSC is credited for 60 lbs/year of nitrogen removal, 54.4 lbs/year phosphorous removal, & 34,720 lbs/year of total suspended solids (Burch et al., 2014).

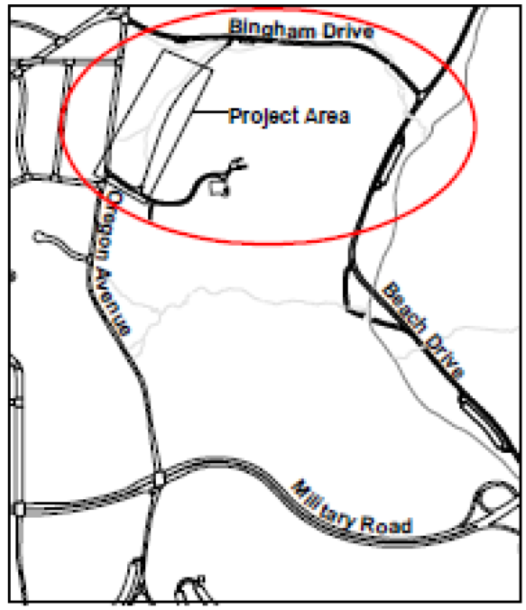


Figure 3.10: A map of the project area around Bingham Run RSC (NPS,2011)

Along the western side of the conveyance channel is the Western Ridge Trail, a historically significant hiking and walking trail. On the East side of the conveyance is the remnants of Old Bingham Road. While at the site it was observed that as much foot traffic occurred on the Western Ridge Trail as that which occurred on Old Bingham Road.

Preconstruction Erosion and Need

Prior to implementation of RSC techniques; increasingly powerful and high-volume stormwater flows had scoured the banks of this ephemeral stream,


Figure 3.11: An image of channel degradation prior to construction of Bingham Run RSC

undercutting surrounding trees and other vegetation, and exposing utility lines, including sanitary sewer pipes (see figure 3.11). In addition, eroded soil from the banks had been carried downstream, damaging aquatic habitat. Instead of natural waterways characterized by step pools and surrounding vegetation, the headwater stream flowed in a severely eroded and deepened channel. The degradation of the headwater channel was linked to the significant increase in stormwater flow quantity from the increase in impervious surfaces in the sub watershed through the years. (US NPS, 2011)

RSC was selected in order to rehabilitate and stabilize Bingham Run. Furthermore, “Hard engineering alternatives such as […] gabion baskets, rip-rap, or similar hard armoring was dismissed as inconsistent with NPS policies, project goals, and fiscal constraints” (US NPS, 2011)

Site Design and Site Visit

In order to build the RSC design at this site an Environmental Assessment and Assessment of Effect report were required under The National Environmental Policy Act. These reports were prepared by the National Park Service (NPS). NEPA requires federal agencies to assess the environmental impacts of federal projects and disclose these impacts to the public partially by creating the aforementioned reports.

Figure 3.12: A panoramic photograph from the historic Western Ridge Trail looking towards the RSC, illustrating the inconspicuous nature of the RSC and plantings

In regards to the RSC it appears heavily naturalized and was almost completely undiscernible that it exists (see figure 3.12). This is perhaps due to the channels distance from the path and/or the level of overgrowth on the banks. The native plantings did not visually stand out and often times the areas of native plantings were not conspicuous and looked like any other area of the understory. In many of these planting areas invasive wineberry (*Rubus phoenicolasius*) and other herbaceous plants, grasses and shrubs were as conspicuous as the native plantings. Beyond wire mesh deer rings, there is nearly no evidence that any plantings have been done. No signage depicting prior conditions were present along the RSC; and due to this there was no frame of reference for viewers to compare and contrast preconstruction conditions from post installation conditions.

During the site visit an aspect that stood out was that the average channel slope of the RSC slope was relative to the other two RSC precedents. Towards the lower-middle section of the conveyance and near the eventual outfall, exist some large weir dams of approximately 8' height (see figure 3.13). At bank full the area behind these weir dams could potentially extend to a longitudinal distance of ≈50'; with a considerable amount of above ground water storage (perhaps in order to mitigate discharge for larger storm events). In these pools the banks could be very steep at a grade of ≈1:1 (100%) or greater. Bank full depth of the pools could easily reach a depth of 5'. In this way some of the pools seemed to mimic a natural detention pond; these ponding areas were, by far, the largest encountered at any of the three RSC precedents mentioned in this chapter.

Figure 3.13: A photograph of an implemented weir dam at Bingham Run RSC

At the time of the site visit, in mid-October, a prolonged period with minimal rainfall resulted in very low amounts of recent stormwater contribution to the channel base flow accept in the way of that from the water table recharge. With this in mind, there was only one area in the entire RSC where water had pooled. There was no noticeable area of flowing or trickling water including at the outfall of the RSC.

Site Vegetation

A vegetation survey of the proposed project area was conducted in May 2010, by Biohabitats, and later confirmed by Rock Creek Park natural resource specialists. Some native over story trees documented are: black walnut (*Juglans nigra*), tulip tree (*Liriodendron tulipifera*), northern red oak (*Quercus rubra*) and red maple. Some native understory plants identified were several dogwood species (*Cornus spp.*), poison ivy (*Toxicodendron radicans*), Virginia creeper (*Parthenocissus quinquefolia*) and northern spicebush (*Lindera benzoin*). 32 species and genus of plants were identified all together; 12 of which were non-native or invasive.

During the site visit it was noted that the majority of the forest canopy trees were composed of tuliptree (*Liriodendron tulipifera)* and some specimens directly along the channel reached heights of ≈100-120 feet with a few specimens reaching diameter at breast height (DBH) of ≈5ft (see figure 3.15). The native understory shrub, northern spicebush, was present in very large numbers near the northern side of the site (see figure 3.14).

Figure 3.14: An image of an area of understory shrubs dominated by spicebush

Figure 3.15: An image of several mature tuliptrees near Bingham Run RSC

Linnean Gully RSC

Site Context & RSC Performance

Linnean *Gully* RSC, not to be misconstrued with the RSC undertaken close by at Linnean Park; was contracted by the Washington D.C. Department of Energy and the Environment (DOEE, formerly known as the District Department of the Environment) and partially funded by the National Fish and Wildlife Foundation. The RSC is located in Soapstone Valley Park, within the northwestern Washington D.C. low-density residential neighborhood of Forest Hills. The RSC conveys water from a contributing area of 18.46 acres that flows through the outfall pipe near the top of the site (Underwood & Associates, 2016). The channel is a tributary headwater to Broad Branch [stream] which flows into Rock Creek and then to the Potomac River.

Topographically the site and channel are on a ridge with a total elevation change of 40 feet and the channel runs for only 143 linear feet; making it one of the steepest RSCs the design and build firm, Underwood and Associates, had ever implemented (Underwood & Associates, 2016). Near the toe of the ridge the channel crosses the Soapstone Valley Trail which travels east and west along the main valley creek offering access into the Rock Creek Park trail system.

The Linnean Gully RSC was credited for 24 lbs/year of nitrogen removal, 21.8 lbs/year of phosphorous removal, and 13,888 lbs/year of total suspended solid removal (Burch et al., 2014).

Preconstruction Erosion and Need

Figure 3.16: A photograh of a pipe outfall foundation failure at Linnean Gully (Used with the permission of Underwood & Associates)

Stormwater flows from the pipe outfall had led to an incised receiving channel. The substrate directly underneath the outfall had begun to undercut leading to the structural failure of the flared outfall base, which fell into the incised channel (see figure 3.16). The channel incision continued for the entire run of the channel to the eventual channel outfall into the receiving stream.

Site Design and Site Visit

During the site visit things that particularly stood out about the site is that of all the sites visited it is by far the steepest site; 90% of the site consists of grades of at

Figure 3.17: Images of Linnean Gully RSC post construction at the toe of the ridge (left) and (right) the RSC post construction near the middle of the ridge (Used with the permission of Underwood and Associates)

least 1:4 and there are several areas around the channel that have grades over 1:1 (see figure 3.17)

The site design is similar to the others in materials utilizing large sedimentary stones of between ≈500lbs and 2 tons at the riffles (or cascades); in conjunction to utilizing downed trees and on site trees marked for removal as natural dams laid across the channel at varying intervals. The channel base is largely covered with high quartz content cobble which has partially been chosen for its aesthetic appeal (May, 2016) and likely to armor the bank against erosion, while providing for continued infiltration and resisting displacement during high flow events.

This design also includes a curb cut from the street to allow flow directly from the street; this leads to some minor "daylighting", more opportunity for infiltration and some energy dissipation through a brief swale as opposed to using street gutters and pipes.

Figure 3.18: One small ponding area during a storm event (Used with the permission of Underwood and Associates)

While the ponding areas available are small, due to the high site gradient of the site; some small pools have been created (see figure 3.18) which further allow for infiltration treatment and settling of suspended solids; in conjunction with the typical highly hydraulically conductive sand and compost substrate utilized in RSCs while raising the channel height.

Site Vegetation and Ecosystem

Despite the small site footprint of Linnean Gully RSC, the preconstruction woody plant material (not herbaceous) consisted of good variety. Overstory and understory trees consisted of white oak (*Quercus alba*), sugar maple (*Acer saccharum*), American hornbeam, tuliptree, American beech, American holly (*Ilex opaca*), American sycamore, black cherry, some hickory specimens (*Carya spp.)* and eastern hemlock (*Tsuga canadensis*).

However, the understory layer, particularly adjacent to the site disturbance area, is heavily dominated by two invasive shrubs: burning bush (*Euonymus alatus*) and Japanese honeysuckle. Lastly, the invasive overstory tree, Norway maple (*Acer platanoides*) also existed on site.

Figure 3.19: A photograph of post-construction vegetation around the channel; including native plantings or iris and sweetbay magnolias

Newly planted vegetation in the area consisted primarily of ferns, blue flag iris (*Iris versicolor*), and sweetbay magnolia in close proximity to the channel. This was the only instance of the magnolia bog species sweetbay magnolia being incorporated into a planting among any of the precedent study RSCs. Moss was present frequently around the channel, also; but it could not be determined if the moss was naturally occurring, or if it had been brought to the site during construction.

Problems and Concerns

Unfortunately, like Briers Mill Run RSC, Linnean Gully RSC had a partial blowout some time in 2017. As of now, no conclusion was drawn to the cause of this blow out. To speculate: the large slope of the sight, at ≈28% average slope may require greater design precautions such as ensuring footer boulders of cascades extend into existing soil, while ensuring that cascades are set at slopes that conform to the design chart suggested in step four of the 2012 Anne Arundel County Design Guideline Manual.

CHAPTER 4: SITE ANALYSIS AND METHODS

Site Selection and Site Description

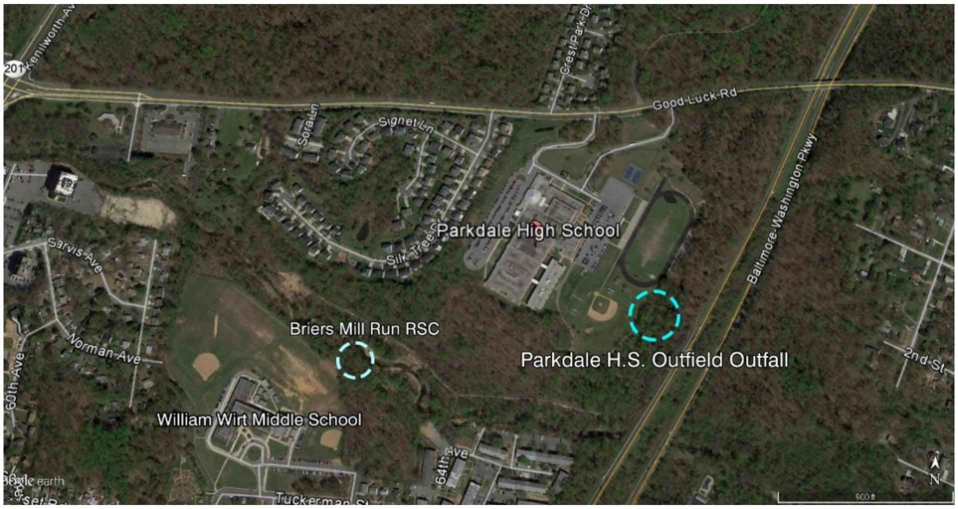


Figure 4.1: A map of the area around the selected site, and the site relative to Briers Mill Run RSC

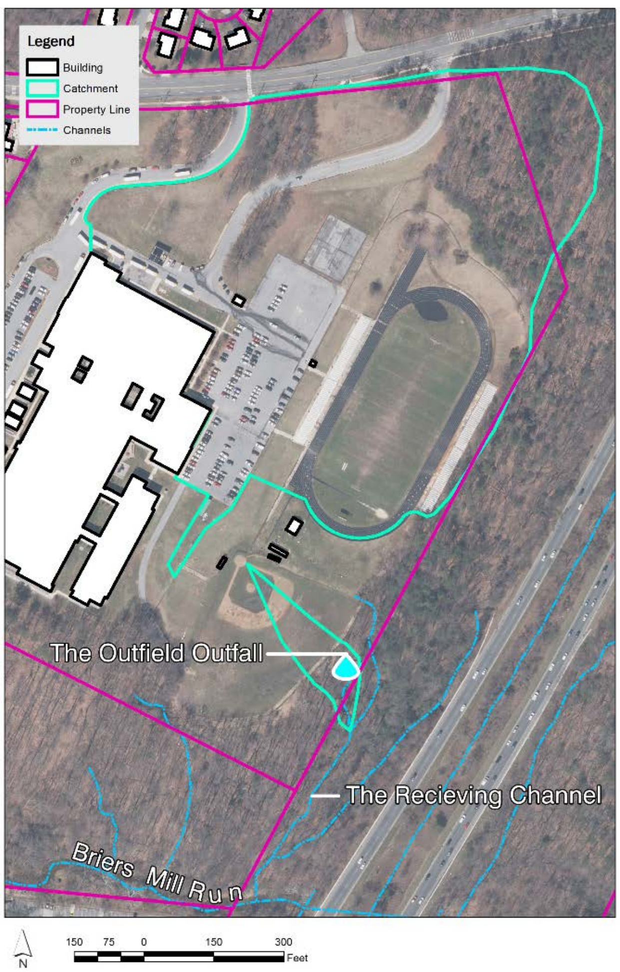


Figure 4.2: A map of the Outfield Channel Outfall

Parkdale High School in Riverdale Park Maryland was selected as the demonstration site, when a highly degraded channel was discovered in spring of 2016. This channel originates from a stormwater pipe outfall and headwall on the southeastern corner of the property. Near the outfield of the baseball field (see the water drop symbol in figures 4.2). The initial stormwater channel reach, hereafter referred to as, “the Outfield Channel” flows from a 30” diameter pipe to the south for 160’, horizontally, before converging with another stormwater channel into a receiving channel. The receiving channel runs for approximately 430’ before flowing into Briers Mill Run. The Outfield Channel initially runs for approximately 100’ on Prince George’s County Public School (PGCPS) land before flowing into NPS land.

Figure 4.3: Images of the Outfield Channel Outfall, headwall and immediate channel

Another reason for the selection of this site, is that it would be *the second* RSC implemented in Prince George’s County while over 20 RSCs have been implemented in the surrounding counties and Washington D.C. *The first* RSC constructed in Prince George’s County, Brier’s Mill Run RSC (denoted in figure 4.1), is located a quarter of a mile downstream of the confluence of the receiving channel outfall. Briers Mill Run RSC functioned as a primary source of reference for the design of the proposed Parkdale High School RSC.

Considering that this RSC would be on Parkdale High School property, implementation would provide an easily accessible and tangible teaching tool for educating high school students on stormwater issues and concerns to Prince George's County high school students; thus assisting in meeting Maryland environmental standards criteria (MSDE, 2011). While Brier's Mill Run RSC is very close as-the-bird-flies, and has been used as a teaching tool for youth at Parkdale High School, it is unfortunately on the opposing side of Briers Mill Run with no convenient bridge access. Additionally, Briers Mill Run RSC is directly to the rear of William Wirt Middle School, *it is not on PGCPS land and is gated from the public* – requiring extra coordination from school teachers and staff.

Demographics

Parkdale High School has a student population of about 2,200 and which is primarily made of minorities (MDSE, 2016). African American and Hispanic students make up the majority of students. These demographics are generally representative of the population in Riverdale Park in 2016.

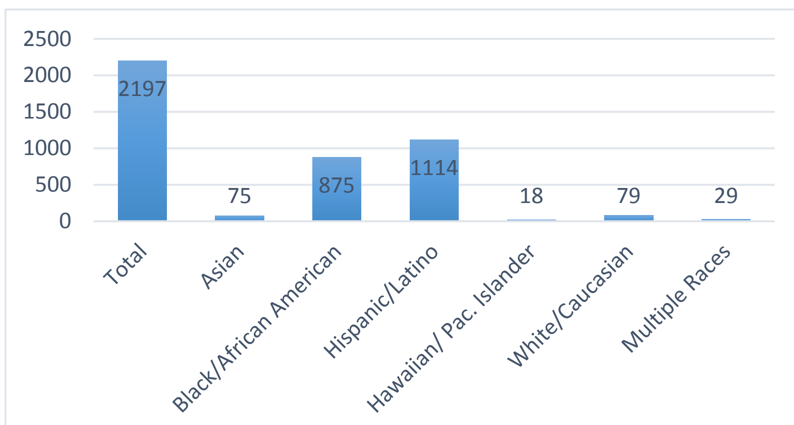


Figure 4.4: A graph of the demographics of Parkdale High School by race

Plant Inventory and Ecosystem Classification

Mature Trees

Figure 4.5: An image of a tuliptree, in bloom, found near the site

The site catchment area at Parkdale High School consists of the following mature trees: many tuliptree (*Liriodendron tulipifera),* abundant sweet gum *Liquidambar styraciflua,* red maple, white oak, red oak and a few large specimen of hickory. North of the football field at the highest elevations on the site scrub pines (*Pinus virginiana*) grow in high concentrations. Towards the lower elevations of the catchment and the outfall of the storm water channel into

Figure 4.6: A north facing view towards mature forest dominated by scrub pine and oaks

Briers Mill Run, red maple, boxelder, American sycamore become prevalent. The primary large invasive species of tree is tree of heaven (*Ailanthus altissima*) which occurs primarily in the ecotone of the upper portion of the site (along the baseball field).

Understory Trees and Shrub Layer

The understory trees and shrub layer is made up of specimens such as many young sweet gum, arrowood viburnum (*Viburnum dentatum*), American hornbeam, American holly, spicebush, and some oak saplings, hickory and American beech (Fagus grandifolia). There exists several understory and shrub layer invasive species; most prevalent being Japanese bush honeysuckle (*Lonicera maackii)* followed by Japanese barberry (*Berberis thunbergii*).

Figure 4.7: An image of understory of American holly and American beech found just east of the site stormwater pipe outfall

Forest Floor and Vines

The forest floor, particularly around the conveyance channels, consists of frequent patches of fern (see figure 4.8 left). Native vines, such as, poison ivy, Virginia creeper, and various greenbrier (*Smilax spp.*) are common around the site. However, significant stands of Japanese stiltgrass (*Microstegium vimineum*) are present in many areas in monotypic stands, which have been linked to the degradation of forest understories and lack of native shrub establishment (Sarver, M.J., et al., 2008).

Figure 4.8: Photographs of invasive Japanese stiltgrass and native fern on the channel banks (left), and (right) invasive porcelainberry around the confluence of the existing channel and Briers Mill Run

Invasive vines such as English ivy (*Hedera helix*) and porcelainberry (*Ampelopsis brevipedunculata*) are abundant on the site. porcelainberry was most prevalent towards the outfall of the channel into Briers Mill Run while English ivy was found mostly around the site's pipe outfall. Some invasive mile-a-minute vine (*Persicaria perfoliata*) and Japanese honeysuckle also are on site.

Ecosystem Classification

Based on the vegetation and geomorphology, the *majority* of the project site ecosystem falls under two Maryland Department of Natural Resources (MD DNR) key wildlife habitat classifications: *Mesic Mixed Hardwood Forest* and the *Coastal Plain Floodplain*. Based on the characteristics of the land, hydrological conditions and vegetation growing within unmanaged areas of the outfield channel catchment it is also possible that small areas can also be characterized as either piedmont or coastal plain seepage swamps, or piedmont or coastal plain stream ecosystems.

Figure 4.9: An image of a Mesic Mixed Hardwood Forest key wildlife habitat (Richard Wiegand, MD DNR)

As stated by the MD DNR: Mesic Mixed Hardwood Forests consist of mixed canopies of [tuliptree], American beech, white oak, northern red oak, mockernut hickory and pignut hickory; and the understory trees consist of small trees such as American holly and pawpaw (MD DNR, 2015). Almost all of these species have been identified in or around the site catchment basin.

Coastal Plain Floodplains are compositionally diverse and occur as a wide variety of forests, woodlands shrublands and herbaceous communities. Floodplain forests of small intermittent streams and braided streams are said to support combinations of American sycamore, red maple, sweet gum, [black tupelo] and river birch (*Betula nigra*) (MD DNR, 2015). Many of these species of canopy trees are represented heavily towards the lower elevations of the site near the outfall of the headwater channel into Briers Mill Run.

The entire site project area is largely unmanaged, and the ecosystems are in the final stage of ecological succession with the exception of the baseball field, football field, parking lots, driveways and buffer strips. Many trees within the forested area have reached diameters at breast height (DBH) at approximately 1’ to 3’; and the maximum tree canopy height peaks at approximately 90’-110’. Mature specimens are abundant throughout the catchment. However, the area around the pipe outfall is marked by significant mature tree die off due to trees uprooting and sliding into the stormwater conveyance channel (see figure 4.10).

*Figure 4.10: A panoramic view of s*everal uprooted mature trees in the Outfield Channel near the stormwater pipe outfall.

Hydrology, Drainage & Soil:

Macro Watershed and Subwatershed

The entirety of Parkdale High School Property and the West Channel catchment is located in the Anacostia River Watershed (see left side of figure 4.11). The site is more specifically located in the Lower Subwatershed of Briers Mill Run Watershed (see right area of figure 4.11). Briers Mill Run flows westward from the southeastern corner of the site eventually emptying into the Northeast Branch of the Anacostia River, which eventually runs into the Potomac River, out to the Chesapeake Bay, and into the Atlantic Ocean, ultimately.

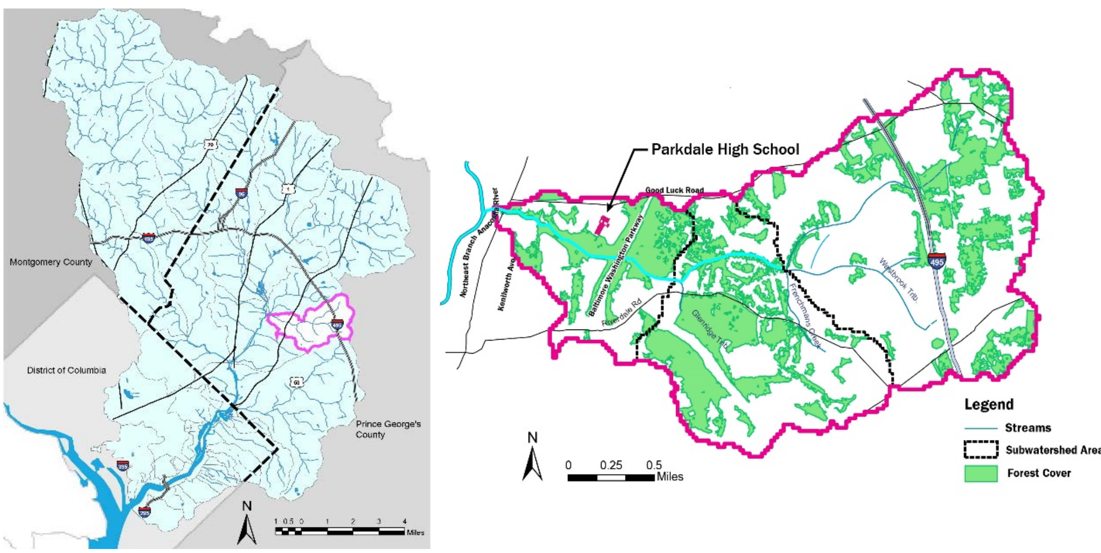


Figure 4.11: Maps of the Anacostia River Watershed (left) and Briers Mill Run Subwatershed (right)

Briers Mill Run Subwatershed is approximately 2,653 acres in area (≈ 4.1 mi^2) and the Lower Subwatershed is approximately 470 acres in area (≈.73 mi^2). Respectively, impervious cover composes 29%(≈ 770 acres) and 25% (≈ 118 acres) of each area; while the tree canopy cover in Briers Mill Run Subwatershed makes up about the same area at 29% of the total area. The remaining area (≈ 42%) of the area can be inferred to be composed of other areas of pervious coverage such as fields, lawn and prairie.

Outfield Channel Catchment Area

The Outfield channel catchment is 17.2 acres in total. About 4.11 acres (23.9%) are forested, 5.15 acres (30%) are impervious with the lion's share (46.2%) is gardens, lawn, prairie or other pervious surface (as illustrated in figure 4.11).

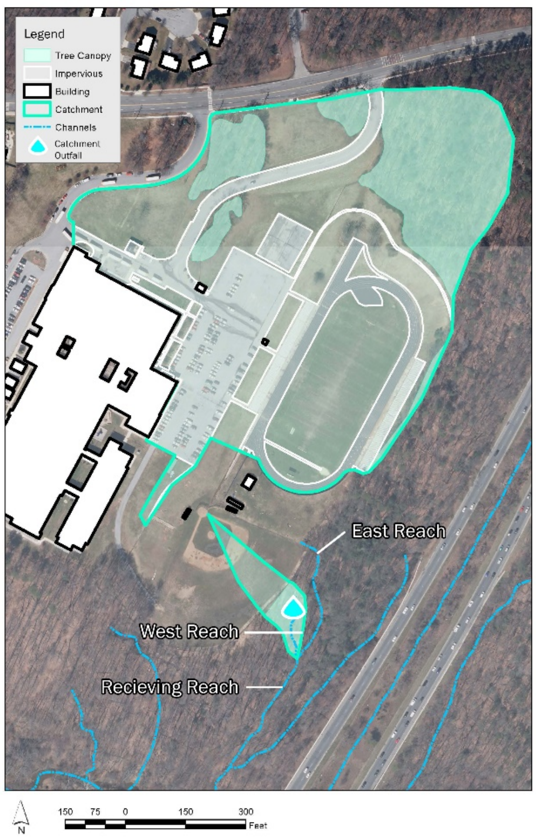


Figure 4.12: A map of the Outfield Channel catchment and impervious, pervious and tree canopy

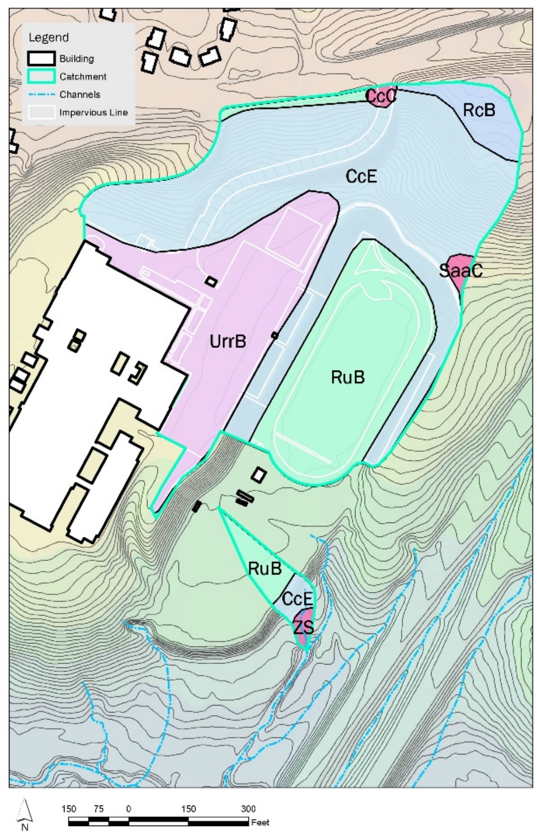


Figure 4.13: A soil map of catchment and topography (Soil Group explanations can be found in table 3.1)

Soil Groups and Properties

According to the soil report generated through the United States Department of Agriculture (USDA) Natural Resources Conservation Service (NRCS), the Outfield channel catchment is largely composed of four main soil types Christiana-Downer Complex (CcC & CcE), Russet-Christiana complex (RcB) Russett-

Prince George's County, Maryland			
Map Unit Symbol	**Map Unit Name**	**Acres in AOI**	**Percent of AOI**
CcC	Christiana-Downer complex, 5 to 10 percent slopes	0.1	0.4%
CcE	Christiana-Downer complex, 15 to 25 percent slopes	8.2	47.8%
RcB	Russett-Christiana complex, 2 to 5 percent slopes	0.6	3.5%
RuB	Russett-Christiana-Urban land complex, 0 to 5 percent slopes	4.1	24.0%
SaaC	Sassafras sandy loam, 5 to 10 percent slopes, Northern Coastal Plain	0.1	0.8%
UrrB	Urban land-Russett-Christiana complex, 0 to 5 percent slopes	4.0	23.0%
ZS	Zekiah and Issue soils, frequently flooded	0.1	0.5%
Totals for Area of Interest		**17.2**	**100.0%**

Table 4.1: A description of soil groups in the western catchment

Christiana-Urban land complex (RuB) and Urban land-Russet-Christiana (UrrB). These areas make up almost 99% of the catchment area.

Soil Group	HSG
CcE	A: 45% D: 55%
RcB	C: 50% D: 50%
RuB	C: 33% D: 67%
UrrB	C: 10% D: 90%

Table 4.2: A description of the four main soil groups broken down by their hydraulic soil groups

A deeper explanation of the soil drainage properties of these four major groups can be attained via table 4.1; which also depicts site slopes, generally. Furthermore, table 4.2 depicts hydrologic soil groups (HSG) makeup of the four major soil groups in the Outfield channel catchment. “A-soil” is considered to have very high hydraulic conductivity; while “D-soils” have very slow drainage properties, nearing imperviousness. The catchment can thus be described as being composed of largely poor draining soil based on the vast majority of area labelled as being composed of C and D soils.

While the catchment area is characterized by four main soil groups; the area immediately adjacent to the Outfield channel is composed of two main soil groups primarily: Christiana-Downer complex soil (CcE) and Zekiah-Issue soil (ZS). These two soil groups are composed of all four HSGs from A to D. The soil drainage in the area is, thus, considered to be average.

Site Drainage and Topography

The Outfield channel catchment drainage is composed of large areas that are nearly flat (e.g. the rear parking lot, the football field, and the baseball field) have gradients of 0 to 5% (see areas labelled RuB and UrrB in table 4.1). However, the site is also composed of large areas with high gradients, as stated before. The football field is like a very large amphitheater and is surrounded by steep slopes on all sides except to the south (see figure 4.14). Similarly

Figure 4.14: Top: A southward view of the southern end of the football field toward the outfall l, and a northward view looking at the “amphitheater” like quality of the football field and surrounding slopes (bottom)

the entirety of the northern extent of the catchment is composed of moderately steep to steep gradients: Notably, 47.8% of the site is composed of slopes at 15% to 25% as denoted in table 4.1. The highest point in the catchment is located north east of the football field, and the whole northern extent of the catchment, near Good Luck Road, drains toward the south. The general slope on site is from the northwest to the southeast.

Figure 4.15: A topographic map of the catchment with 2ft contour lines (brown represents the highest elevation while blue denotes the lowest elevation)

The general drainage pattern of the site can be seen in figure 4.17 on the following page. Generally drainage follows the slope of the site, however there is a

Figure 4.16: A panoramic photo from the top of the ridge on the northwestern side of the football field (Particularly of note: is a concrete drainage ditch around the entire northern extent of the field)

large concrete drainage ditch which completely surrounds the northern extent of the football fields (see figure 4.16).

Drainage is also aided and hastened on the site by the addition of 26 outlets mapped in figure 4.17 (inlets are depicted as small black squares). About half of these inlets are at the top of the ridges and bleachers surrounding the baseball field and football field; while the other half is located at the base of the bleachers around the football field and track. The most hydrologically distant point of the catchment was found to be approximately 1700 feet away from the stormwater pipe outfall. The dark blue line in figure 4.17 represents the path water travels from this point. The estimated time of concentration, the time for water to traverse the distance from the most distant point to the catchment outfall, is about 8 minutes and two seconds (more in depth discussion of how this was calculated can be found in chapter 5)

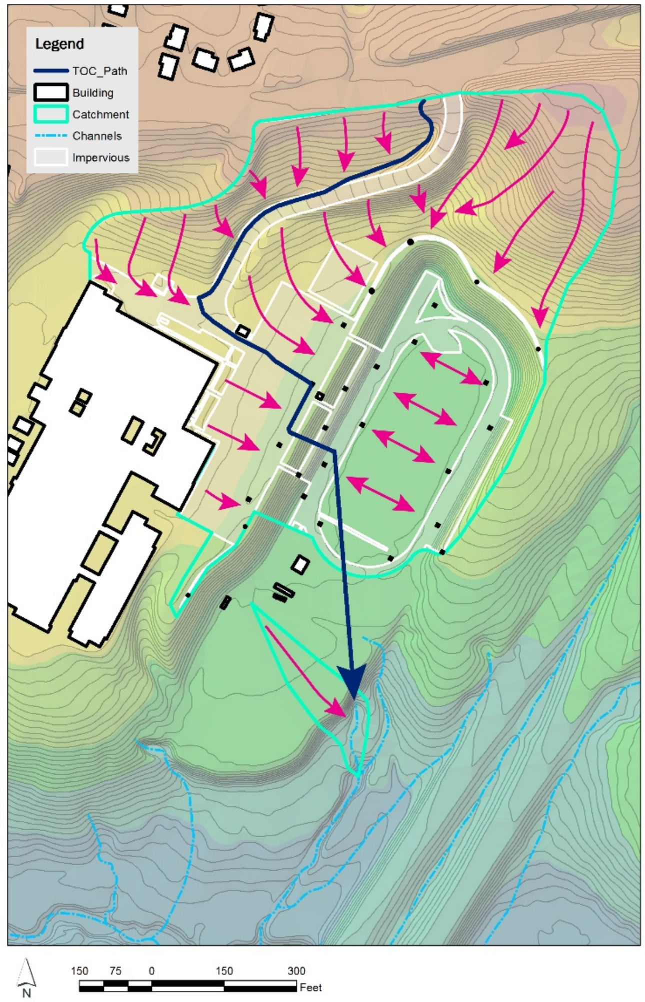


Figure 4.17: A drainage map displaying the path from the most hydrologically distant point in the site and general drainage

Existing Degradation & Erosion:

As stated before, a major impetus to the selection of this site, is the existence of extreme stormwater channel incision and erosion in the Outfield channel. Incision and active erosion exist in the receiving channel as well (see figure 4.18); however the most severe erosion is located in the Outfield channel stormwater reach.

Figure 4.18: Top: A northward view of a highly eroded area just south of the Outfield Channel, and another area of active erosion in the receiving channel (bottom)

The incision of the channel has gotten so severe that, as stated before, almost a dozen mature trees have fallen into the stormwater channel. Furthermore, there is no area in the western reach that does not have an average bank height less than 8ft in

Figure 4.19: A southward panoramic view of the outfall pipe depicting the level of erosion on the southern bank of the Outfield Channel (for reference: the white pole in the center is 20' in length).

height. In areas the bank heights are over 11 feet and the banks angle of repose is generally greater than 66 degrees (or 250% slope). The level of incision and high angles of repose are depicted in the surveyed channel sections (see figure 5.3 and appendix A.1) and the channel profile (figure 5.15). In the area immediately west of the Outfield Channel pipe outfall and headwall there is an area of soil slump in the outfield of the baseball field that has led to the replacement of a short span of the outfield fence. In all likelihood this was damage was caused by severe ridge erosion into the Outfield Channel (see 4.19).

CHAPTER 5: DESIGN

Process

Surveyed Topography Versus Prince George's County LIDAR

When beginning the design phase of the west channel stormwater channel; it was immediately apparent that the topography depicted by the topographic two foot contours Prince George's County GIS Open Data website did not accurately depict the actual conditions on site as seen in figure 5.1.

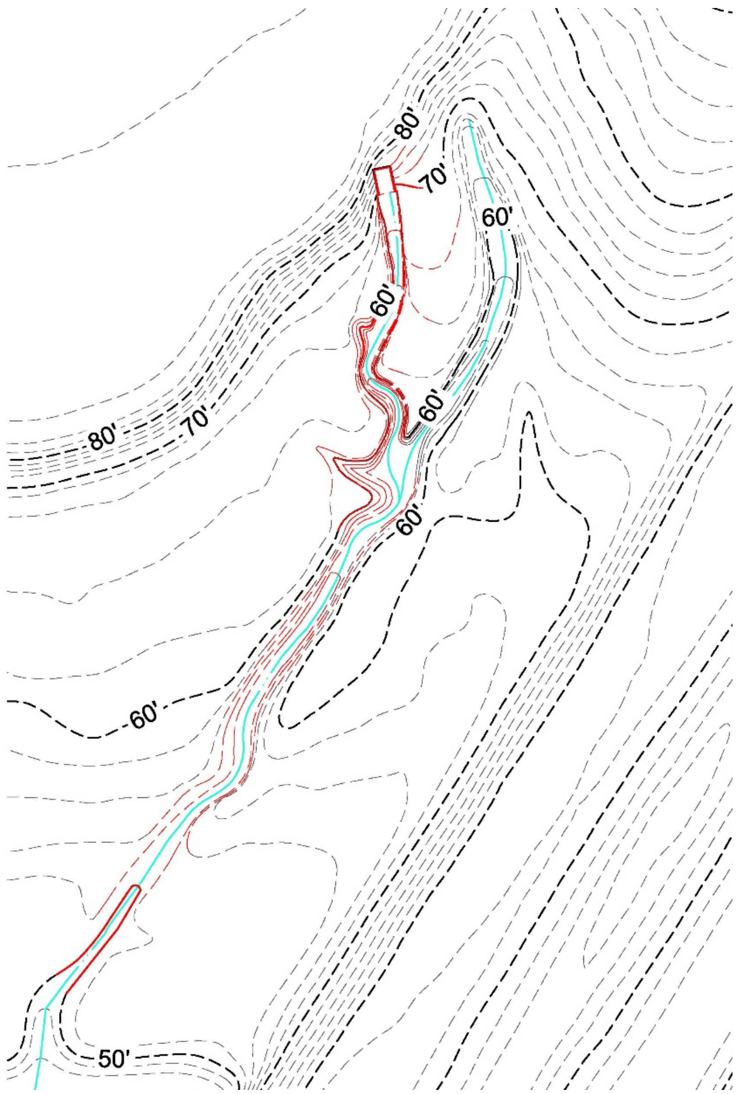


Figure 5.1: A topographic map of the Outfield Channel and receiving channel displaying all topographic lines that were modified (red topographic lines were recreated).

In order to get a more precise depiction of the topography in the Outfield Channel a topographic survey was undertaken along the centerline (C.L.) of the existing channel (represented by cyan in figure 5.1 and figure 5.2). Due to the drastic gradients of the side banks and the density of the underbrush along the

Outfield Channel it was deemed impractical by the thesis committee members present at the time of the survey to undertake a typical site survey with use of a laser level, which would produce a grid of measurements from a known point of reference. Instead it was deemed more practical to simply use the telescoping measuring rod to get a vertical and horizontal measure at 25’ increments

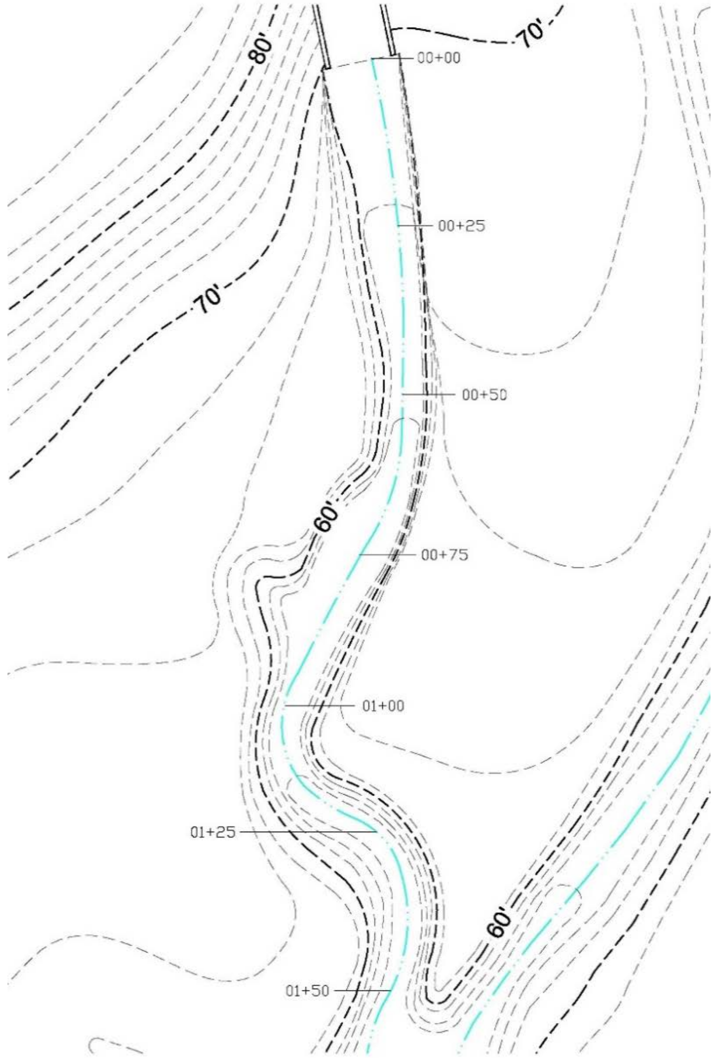


Figure 5.2: A two foot contour topographic map of the Outfield Channel which was derived from on-site survey.

Figure 5.3: Left: an image of the second vertical measure of station point 1+25, and the subsequent cross section (right)

following the channel C.L. Multiple photographs were taken at each 25 foot increment station point measurement. The images display a vertical or horizontal measure (examples are shown in figure 5.3 and figure 5.4). From these photographs seven cross sections were produced (also in figure 5.3 and the remainder in appendix 1.1). With these seven sections an educated reference point was chosen for the first and last station point and then the in-between sections were arranged in a manner along the centerline that produced a consistent longitudinal channel slope. The existing topographic plan was derived via this process.

Figure 5.4: A photograph of a horizontal channel measurement at station point 1+25

Design Decisions

When beginning to design the Outfield Channel RSC the existing headwalls and outfall pipe were deemed to be in satisfactory condition; so it was decided upon that both would remain at the inlet of the RSC.

Secondly, it was decided upon by the committee for purposes of workload to only address the Outfield Channel and leave the receiving channel and the other headwater stormwater channel directly to the east. The receiving channel and the other headwater channel that feeds into it are both in need of retrofitting. Both of those channels have high side banks, almost 6 feet or greater in depth, ubiquitously. Furthermore, the detention ability of the receiving stormwater channel is likely three to five times that of the Outfield Channel making it a particularly good candidate for detention of stormwater in the Briers Mill Run watershed.

It became evident that having extended the RSC into the receiving channel area would require less grading on the pool and cascade banks because of the need to tie into the receiving channel and avoid an overly large final cascade. However, this design aspect subtracts from the fill required in the RSC which counterbalances the need for grading (i.e. as the final cascade height in the RSC increases fill depth in all areas up-channel also increases, significantly.)

A number of steps in the design process were taken from the 2012 Anne Arundel County Step Pool Storm Conveyance Design Guidelines manual, hereafter referred to at the Anne Arundel County Design Guidelines manual (AACDG). One pivotal part undertaken were those related to designing a weir capable of withstanding a 100 year storm event. Initially, the AACDG was used exclusively to guide design of the general RSC longitudinal profile and the placement and sizing of riffles, pools and cascades.

Weir Sizing: Finding Peak Flow with Win TR55

The sizing of weirs is a technical process and starts in the first step of the AACDG. This step requires that the selected area catchment is delineated. This process was already undertaken using the program ArcGIS. The catchment perimeter was found by finding all areas that would drain to the west channel outfall point via gravity.

After this step was completed the next step was to use the USDA NRCS analysis tool, Win TR55, to find several statistics of the catchment. These are: time of concentration, the catchment adjusted runoff coefficient, and peak flow during a 100-year storm. The AACDG scope does not cover delineation of watersheds nor how to use TR55. However, Win TR55 can be accessed for free online through the NRCS, along with a general user guide and tutorial.

To use Win TR55 the first step is to simply download it online and install the program on a Windows running computer. After the program is installed and running on the initial window, select the “start” button which opens the “Main Window”. On this window fill in the outlined sections in figure 5.5

After these prompts have been filled in, the next step is to download storm event data for the appropriate county. This data includes 24-hour rain fall amounts for storms from a 1-year storm event to amounts for the 100-year storm event. This information can be found by first selecting the drop down tab “GlobalData” and then selecting the option “Storm Data”. Assuming a county had been selected in the previous step; clicking the button “NRCS Storm Data” will populate the storm data fields. If done correctly the window will look similar to that found in figure 5.6.

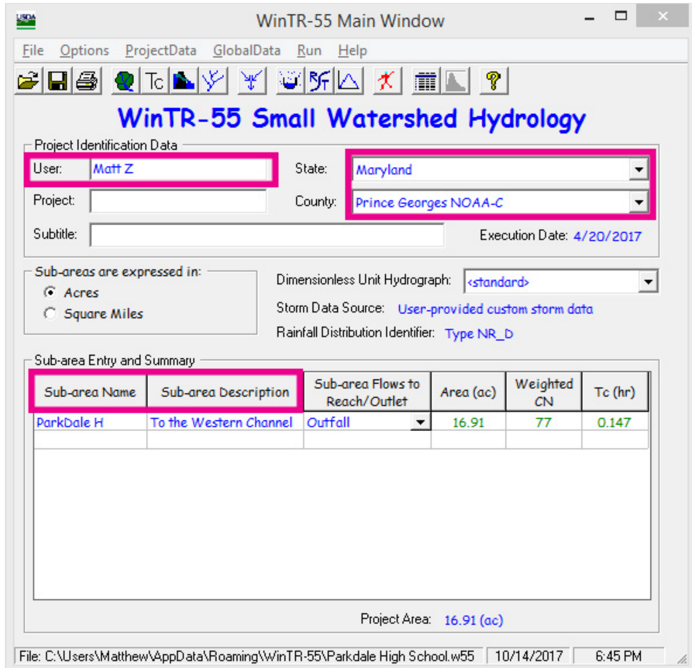


Figure 5.5: Step one: Inputting data into the “Main Window”

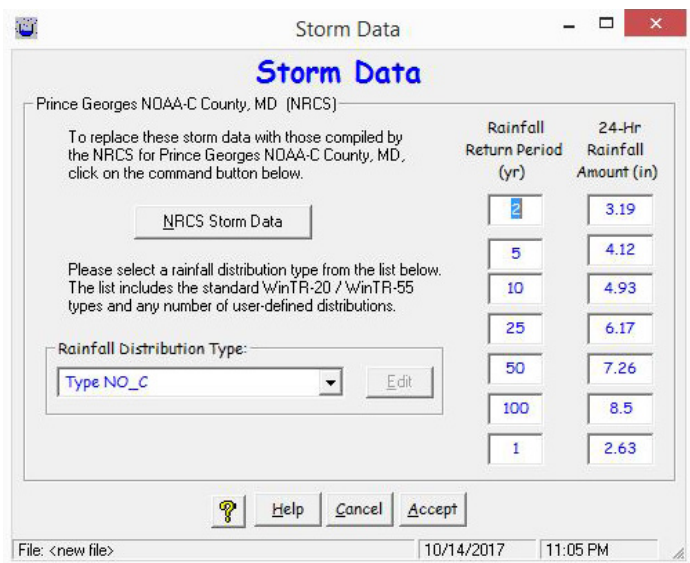


Figure 5.6: Step two: What the “Storm Data” window will generally look like after importing NRCS Storm Data

The following step is to input land and soil characteristics of the project site. In the instance of this project, ArcGIS data on soil was found through the NRCS soil data website and tree canopy and impervious data were found through the Prince George's County GIS Open Data website. After intersecting the soil data areas with impervious areas, pervious areas and areas covered by tree canopy the data in table x.x was produced. This data was created manually in GIS then entered into the "Land Use Details" window of Win TR55. The "Land Use Details" window can be found by selecting the drop down tab, "ProjectData" and then selecting "Land Use Details". By inputting area data into this window a weighted runoff curve number can be

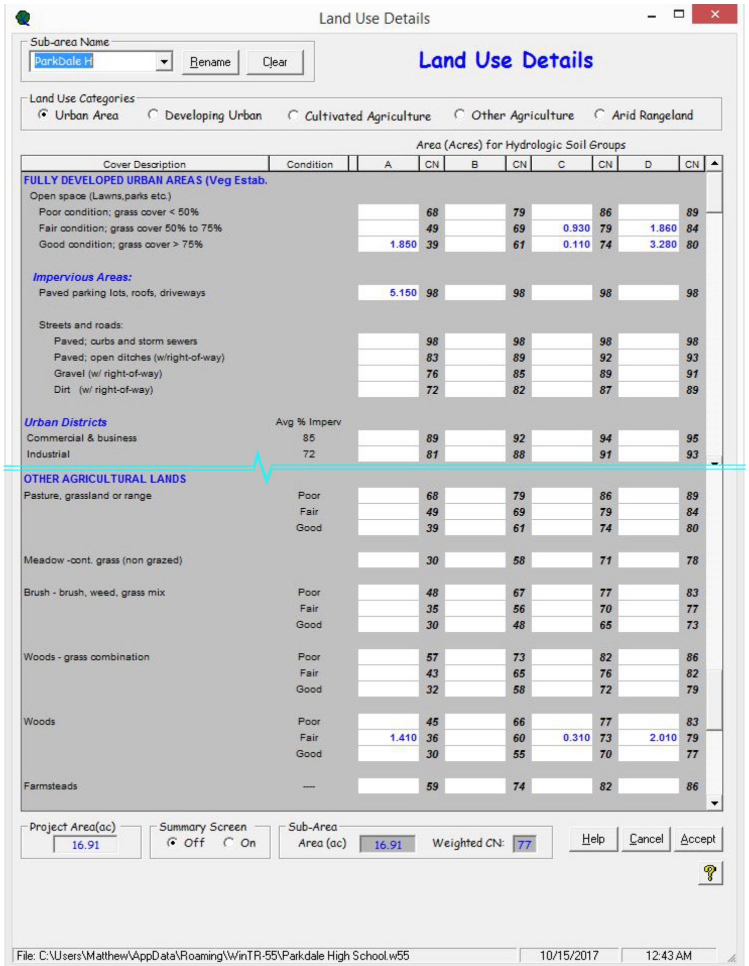


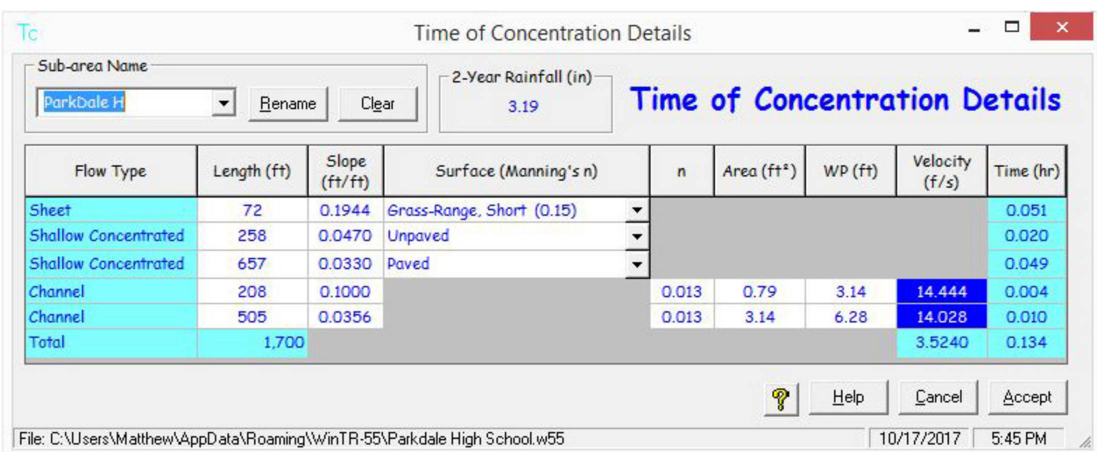
Figure 5.7: Step three: Inputting data into the "Land Use Details" Window which produces a weighted runoff curve number

Soil Group	Tree Canopy (Ac)				Pervious (Ac)				Impervious (Ac)	Total (Ac)
	A	C	D	Total	A	C	D	Total		
CcE	1.41	-	1.72	3.13	1.85	-	2.25	4.10	1.10	8.23 [47.8 %]
RcB	-	0.31	0.31	0.62	-	-	-	-	-	0.62 [3.6%]
RuB	-	-	-	-	-	0.93	1.86	2.79	1.18	4.14 [24.0%]
UrrB	-	-	-	-	-	.11	1.03	1.14	2.82	3.96 [23.0%]
Other	-	-	-	-	-	-	-	-	-	0.27 [1.6%]
Total (Ac)	1.41	.31	2.01	4.11 [23.9%]	1.85	1.04	5.14	7.96 [46.2%]	5.15 [30.0%]	17.22

Table 5.1: A breakdown of tree canopy, other pervious cover and impervious cover versus soil groups and hydrological soil groups in the Outfield Channel catchment

produced. For impervious cover time can be saved by ignoring HSGs because the underlying soil does not effect the runoff curve number (CN). The Outfield Channel catchment weighted runoff CN is 0.77, as depicted at the bottom of figure 5.7. After completing the data entry and clicking “Accept” at the bottom right of this window, it will show an area and weighted CN back on the “Main Window”.

The next step is to enter data for the time of concentration. The data window for this can be found under the “Project Data” drop down tab, and is labelled, “Time of Concentration Details”. There will be five flow types available. For the Outfield Channel all five were utilized as seen in figure 5.8. The flow path of water from the most hydrologically distant point is necessary for this calculation and was found via ArcGIS (see site analysis: figure 4.17). After this path was found it was partitioned and classified into the five flow types. These portions of the whole were inputted under the “Length” column along with the slope of the path of flow and the appropriate Manning’s n coefficient. Under the flow type, “Shallow Concentrated” the Manning’s n is simplified into either paved or unpaved. For the Outfield Channel,



Flow Type	Length (ft)	Slope (ft/ft)	Surface (Manning's n)	n	Area (ft²)	WP (ft)	Velocity (f/s)	Time (hr)
Sheet	72	0.1944	Grass-Range, Short (0.15)					0.051
Shallow Concentrated	258	0.0470	Unpaved					0.020
Shallow Concentrated	657	0.0330	Paved					0.049
Channel	208	0.1000		0.013	0.79	3.14	14.444	0.004
Channel	505	0.0356		0.013	3.14	6.28	14.028	0.010
Total	1,700						3.5240	0.134

Figure 5.8: Step four: Finding time of concentration by entering data for all flow paths from the most hydrologically distant point

there was both areas of flow in a grass swale, paved curb and through the parking lot.

For the flow types, “Sheet” and “Channel” the Manning’s n coefficients are slightly more complex; 10 possible coefficients can be found under the “Surface” selection for sheet flow.

For the Outfield Channel: a flow through concrete pipe was simulated for both of the “Channel” flow types. This was done by calculating the area of a 1’and 2’ diameter pipe ($A = \pi r^2$), and calculating the wetted perimeters - labelled, “WP”. For pipes, the wetted perimeter can be calculated by finding the circumference of the pipe ($C = \pi$d). The concrete pipe Manning’s n coefficient was found via the website: www.engineeringtoolbox.com/mannings-roughness-d_799.html. After inputting these variables a flow velocity will be produced for the final “Channel” flow types if applicable and a time of concentration will be displayed at the bottom right. Select the “Accept” button and proceed to the next step.

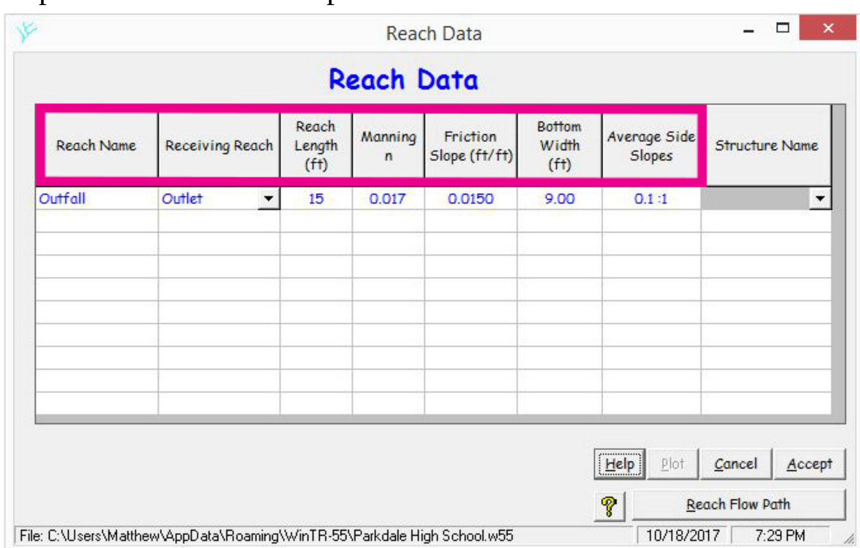


Figure 5.9: Step five (optional): adding additional reaches to the flow path

For the western outfall a small stretch of channel for the existing headwall was incorporated by going to the “Reach Data” window via the “Project Data” drop down tab. The fields in figure 5.9 should be filled in should another small reach area be desired or required. If a reach is incorporated through the “Reach Data” window they should eventually flow to the

“Outlet”. This can be done by selecting “Outlet” under the Receiving Reach column. Furthermore, on the Main Window the subarea should flow to the reach created in the Reach Data window. This is done by selecting the appropriate reach or outlet under the third column.

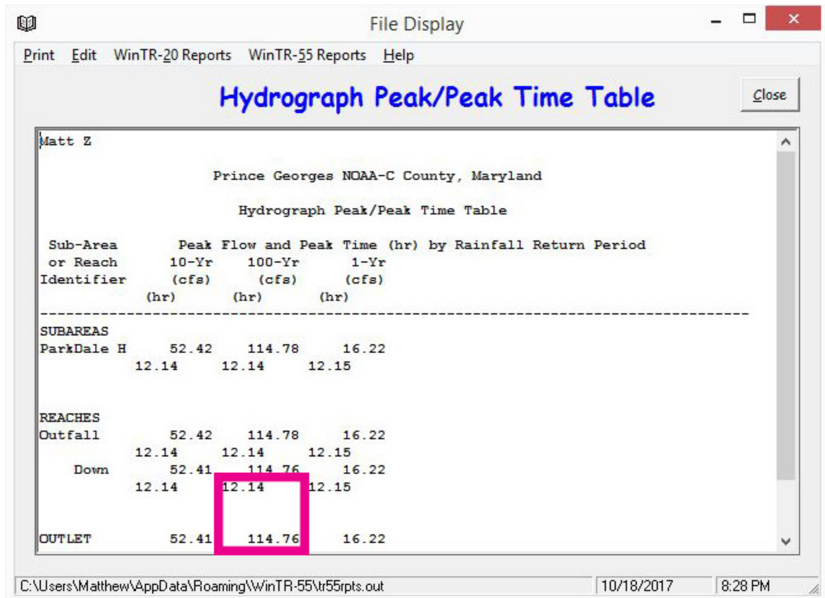


Figure 5.10: A screenshot of the peak flow and peak flow time table

The final step is to run the program by selecting the “Run” tab on the main window and then selecting the desired storm events in the “Run” window. After pushing the “Run” button at the bottom right, peak flow and peak flow times will be collected for the watershed as depicted in figure 5.10. Most important for the weir design is the peak flow, which was calculated to be 114.76 ft^3/sec. In order to convey the 100-year storm the weirs in the RSC need to be able to conduct water at this rate or greater.

It should be understood that there are many simplifications undertaken in the Win TR55 calculations and that is simply the limitation of its use. For instance, as noted by one committee member: it is likely that the pipe section of flow would become pressurized during more intense storms and the pipe would consist of several drop structures. It was decided upon by the designer and committee that Win TR55s calculations would suffice for this design; thus several estimations and simplifications were required.

Weir Sizing: Selecting a Weir Suitable to the 100-Year Storm Peak Flow

Utilizing the AACDG once again, step five recommends the use of parabolic weirs and shows the necessary equations required to find the max flow that a parabolic weir can convey. For the Outfield Channel the final iteration of the weir lead to a 12' wide by 1.5' deep weir. Several variables need to be found for the flow calculation: parabolic area, hydraulic radius and the Manning's n of the channel. The parabolic area is found through the equation:

$$A = \frac{2WD}{3}$$

Where:

W = Width of the weir

D = Depth of the weir

The hydraulic radius is found using the equation:

$$R = \frac{2W^2D}{3W^2+8D^2}$$

The Manning's n for the weir, using a 6" diameter cobble (as recommended in the AACDG), is found using the equation:

$$n = \sqrt[6]{D}/(21.6 \log(\frac{D}{0.5}) + 14)`$$

The calculations for the weir mentioned above are 12.0 ft^2 for parabolic area, 0.96 ft for the hydraulic radius and .044 for the Manning's n coefficient.

After all of these variables are collected the final step to finding the 100 year ultimate flow for the selected weir size is to use the Manning formula:

$$Q = (1.49/n)(A)\left(\sqrt[3]{R_h^{2}}\right)(\sqrt{S})$$

Where:

S = average slope over the entire length of project

The final iteration selected for the Outfield Channel produced an ultimate peak flow of 119.4 ft^3/sec which is sufficient to convey the 100 year peak flow (114.76 ft^3/sec) that was calculated with Win TR55. For simplicity's sake, this was decided to be a typical weir for the entire project. Several weir dimensions were calculated before this weir size was settled upon. The ultimate peak flows of these other potential weirs are shown in table 5.2. Three of these weirs were shown to have flows great enough to adequately convey the 100-year storm peak flow.

Weir Dimensions (Width x Depth)	Parabolic Area (ft^2)	Hydraulic Radius (ft)	Manning's n	Ultimate Flow (ft^3/sec)
12' x 1.2'	9.6	0.78	0.046	82.46
12' x 1.5'	12.0	0.96	0.044	119.40
13.5' x 1.35'	12.15	0.88	0.045	115.15
15' x .75'	7.5	0.50	0.050	44.10
15' x 1.5'	15	0.97	0.044	155.8

Table 5.2: A table of various parabolic weir dimensions and their ultimate flow rates

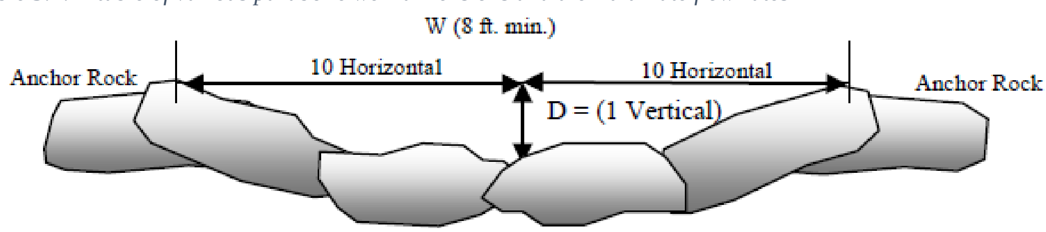


Figure 5.11: A cross section depicting suggested dimensions for RSC boulder weirs (Flores et al., 2012)

The AACDG states that the weirs should have side slopes that are 1V:10H (see figure 5.11 for clarification); however it states "for retrofit projects with limited right of way and/or floodplain constraints, the engineer may increase the cross-sectional entrenchment up to [1V:5H]". Using a weir with side slopes of 1V:10H was quickly deemed unfeasible, because a 15' wide weir with those side slopes could only convey 44.1 ft^3/sec, or about a 1/3 of the 100-year storm event peak flow.

The selected weir size has higher side slopes of 1V:4H. However, it was decided upon that this would be satisfactory for the Outfield Channel RSC, because this weir was shown to convey the 100 year peak flow, it wasn't drastically steeper than the suggested side slope, and also because the Biohabitats engineers strongly supported using simple dimensions and elevations for topographic grading. Lastly, having steeper side slopes also means that less cut will be necessitated, particularly at the outfall of the Outfield Channel (i.e. the RSC will have to return to the existing grade and the channel width at the base is a mere 6' in width versus the 12' width of the typical weir).

Riffle Pool and Cascade Layout Process

AACDG Guided Plans

Initially, it was decided upon that the AACDG was a good framework for the layout of the Outfield Channel RSC. Eventually it was deemed unnecessary to follow, because it is primarily for use in Anne Arundel County and is merely a set of guidelines. However, the AACDG guided plan layouts for the first two iterations of design, and thus, is included.

Some AACDG design specifications that were initially utilized which were deemed unnecessary to follow are:

- Three consecutive pools separated by boulder weir grade control structures shall be used following a cascade.
- Alternate pool and riffle channels.

- Segments utilized for water quality shall not exceed 5% in longitudinal slope.
- The minimum width depth ratio for the pools is [1V:10H].

Some AACDG design specifications that were utilized from cross examination with the Biohabitats Briers Mill Run RSC analysis are:

- Use of a minimum 4 foot cobble apron at the rising limb of pools.
- All unarmored sides of the pool shall be laid at no steeper than [1V: 3H].
- The constructed depth of the typical pools and the pool directly following a cascade shall not be less than 18 inches and shall not exceed 3 feet.
- The minimum depth of the sand/woodchip mix filter medium below the invert of the pools, shall be 18 inches.

For cost reasons it is notable that "a pool geometric design with less than 3 feet of embankment will meet the Code 378 exemption criteria as specified in Appendix B.1 of the State Manual" (Flores et al., 2012). Thus, permitting requirements will be less if pools are kept to a height of less than 3 feet.

Using all of the specifications listed above a layout along the existing channel was created (see figure 5.12). The amount of pools specified by the AACDG is very restrictive, and led to many shallow pools with curving cascades. The latter design aspect may cause issues with erosion on the outer side slope of the weirs/cascades, and also may not be able to convey the 100-year storm due to a skewed

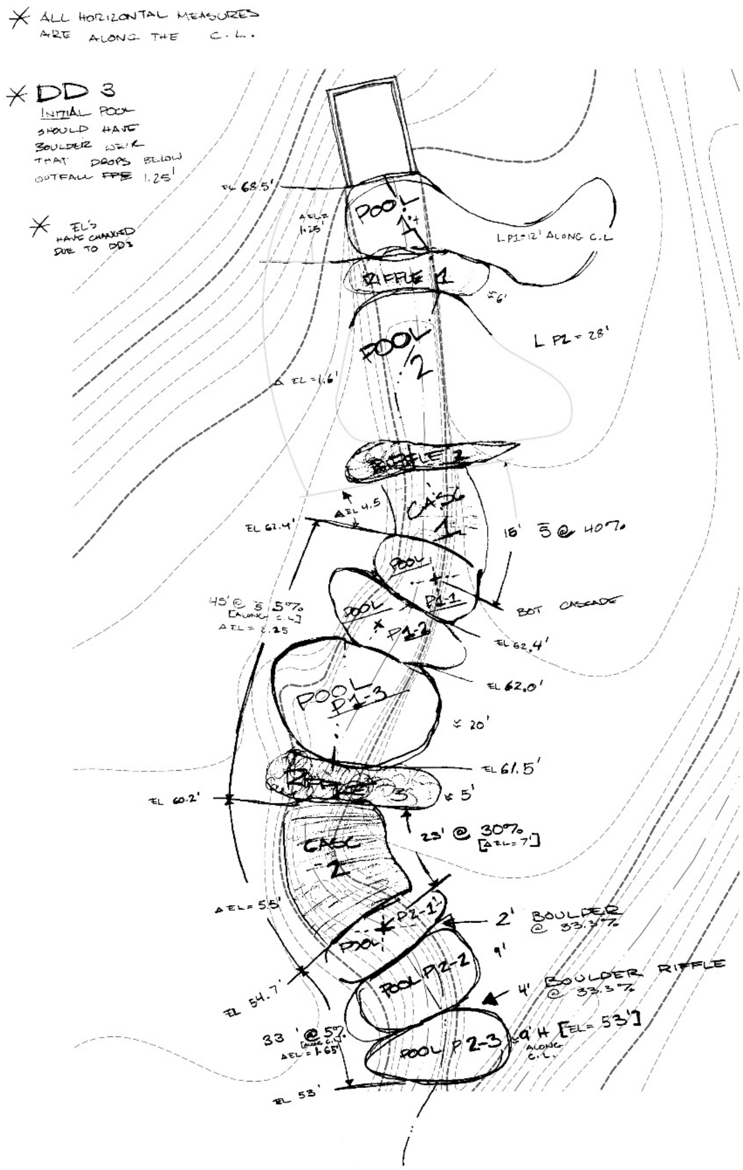


Figure 5.12: A diagram of one of the first pool and cascade layouts for the Outfield Channel RSC (this diagram was derived from the guidance of the AACDG)

weir cross section (i.e. the outside length dimension of the cascade is greater than that of the inner bank).

Briers Mill Run RSC Based Design

After utilizing the AACDG for its restrictions and specifications for several iterations of preliminary design; it was decided upon to analyze the design of Briers

Mill Run RSC in detail; then to use it as a guiding precedent for the Parkdale High School RSC. This seemed especially prudent since the Briers Mill Run RSC is the first and only RSC in Prince George’s County, and furthermore, because it is very similar in watershed size (≈24 acres vs 17.2 acres), overall length (≈132’ vs 160’),

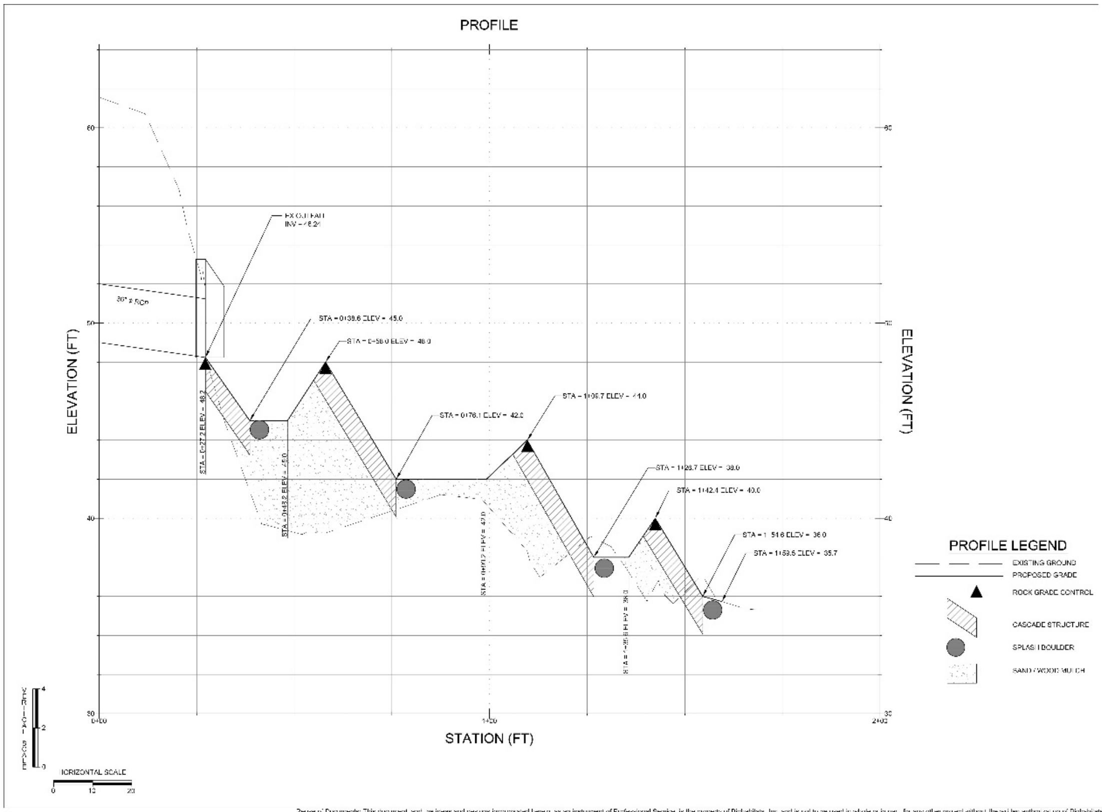


Figure 5.13: A profile diagram of the Briers Mill Run RSC (Biohabitats)

geology and topography.

During the in depth analysis of the Briers Mill Run the planned profile (see figure 5.13) was utilized to produce table 5.3. This table succinctly depicts dimensions, slopes and ratios of the RSC.

	Pool/Riffle Length (L)	Pool Depth (D)	Inlet Cascade Length (Lc)	Inlet Cascade Height (Hc)††	Inlet Cascade Slope (Sc)	RSC Slope	Ratio (L : Lc)
Pool 1	30.1’	3.0’	11.4’	3.3’	28%	-	2.64 : 1
Pool 2	39.5’	2.0’	18.1’	6.0’	33%	-	2.18 : 1
Pool 3	21.3’	2.0’	17.0’	6.0’	35.3%	-	1.25 : 1
Cascade 4	4.9’ †	-	12.2’	4.0’	30%	-	0.40 : 1
Total/ Average	*95.8’*	-	*58.7’*	-	-	**9.5 %**	

†: Doesn’t include Briers Mill Run Channel Width (the receiving stream)
††: Inlet Cascade Height includes vertical depth to the top of the *Weir/Cascade Splash Boulder from the top of the weir crest boulder*

Table 5.3: An analysis of the Briers Mill Run RSC profile section

Notably, the ratio of cascade to pool length decreases in a somewhat linear fashion from 2.64:1 to 1.25:1. Other aspects from Briers Mill Run analysis that were used to guide subsequent design are:

- An initial pool depth of 3’ with shallower pools afterwards.
- Pools are at least 20’ in length along the proposed C.L. and direction of flow in pools changes gradually.
- Cascades are straight and have a straight clearance of at least 5’ past the cascade base.
- Cascades do not exceed 6’ in total elevation change, and are set at ≈33% slopes.

Once detailed analysis of Briers Mill run was complete the cascade and pool preliminary diagram in figure 5.14 was produced. Notable differences are the second design diagrams had half the pools, drastically larger pools (in volume), generally much more typical cascades and much less curving through cascade sections. It was also notable that there would be significantly less cut material relative to the first set of designs. This was due to the orientation change of the ponds (i.e. the ponds had lengths which followed the existing channel line versus ponds that were perpendicularly oriented), and also due to the fact that topography could be designed in a way where elevations more rapidly change. To clarify: the specification of having three ponds after cascades led to a very gradual overall slope through pool sections (see the bottom of figure 5.12).

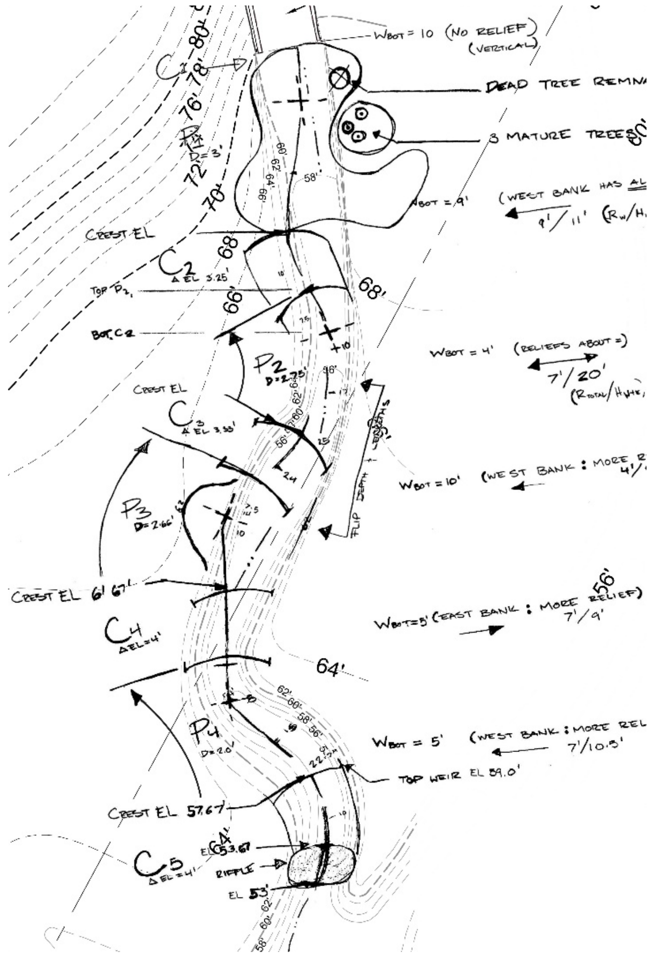


Figure 5.14: A diagram of pool and cascade layouts after analysis of Briers Mill Run RSC

Design

After this final preliminary design a profile section, four sections, a topographic plan, an illustrative plan and a perspective were created to illustrate and communicate the design.

The design profile below illustrates existing elevations of a number of site conditions effectively alongside proposed pool and cascade elevations. For instance, the profile gives an idea of the amount of fill that would be required. Similar to the

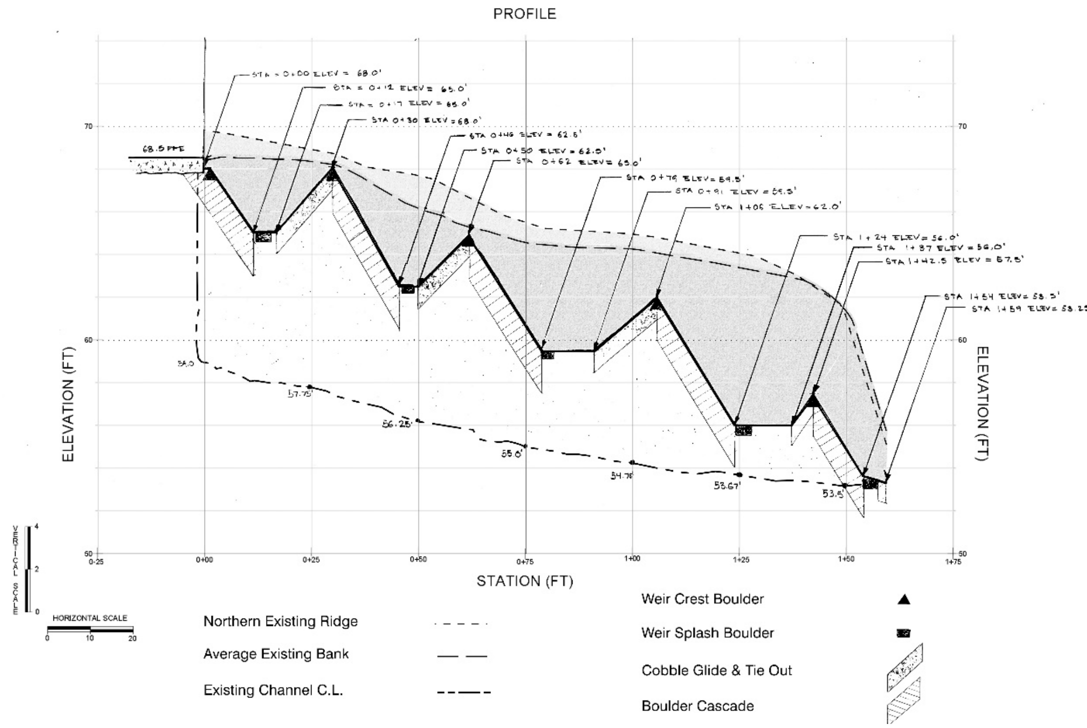


Figure 5.15: The final design profile section

Briers Mill Run RSC the area under the first pool and the following weir require fill to a depth of 8 feet. Furthermore, the profile shows an existing measure for bank heights which is helpful in communicating the consistency of the height difference between the existing channel center line and the bank of the Outfield Channel. As can be seen in the profile, the base of the Outfield Channel is consistently about 10’ below the banks throughout the entirety of the reach. Lastly, it was decided to include a measure for the existing ridge on the northern side of the RSC, because in order to be resilient to the 100-year storm the max pool height had to be high enough not to overtop during that event. Thus, having the ridge line informed subsequent design if a berm would be necessary.

The topographic plan in figure 5.16 depicts accurately slopes around the RSC. It was decided upon by the committee that 2 foot contours did not sufficiently depict topography, so the interval between topographic lines was increased to 1 ft.

Where unarmored pooling areas are, slopes are 1V:3H, as prescribed by the AACDG and as found in the Briers Mill Run RSC. This slope increases to 4V:5H outside of pools. This maximum slope outside of pooling areas were derived from the Briers Mill Run RSC topographic plan.

This plan notably, depicts that on the down channel side of the first and second pool a berm would be required on both sides of the weir for the cascade length

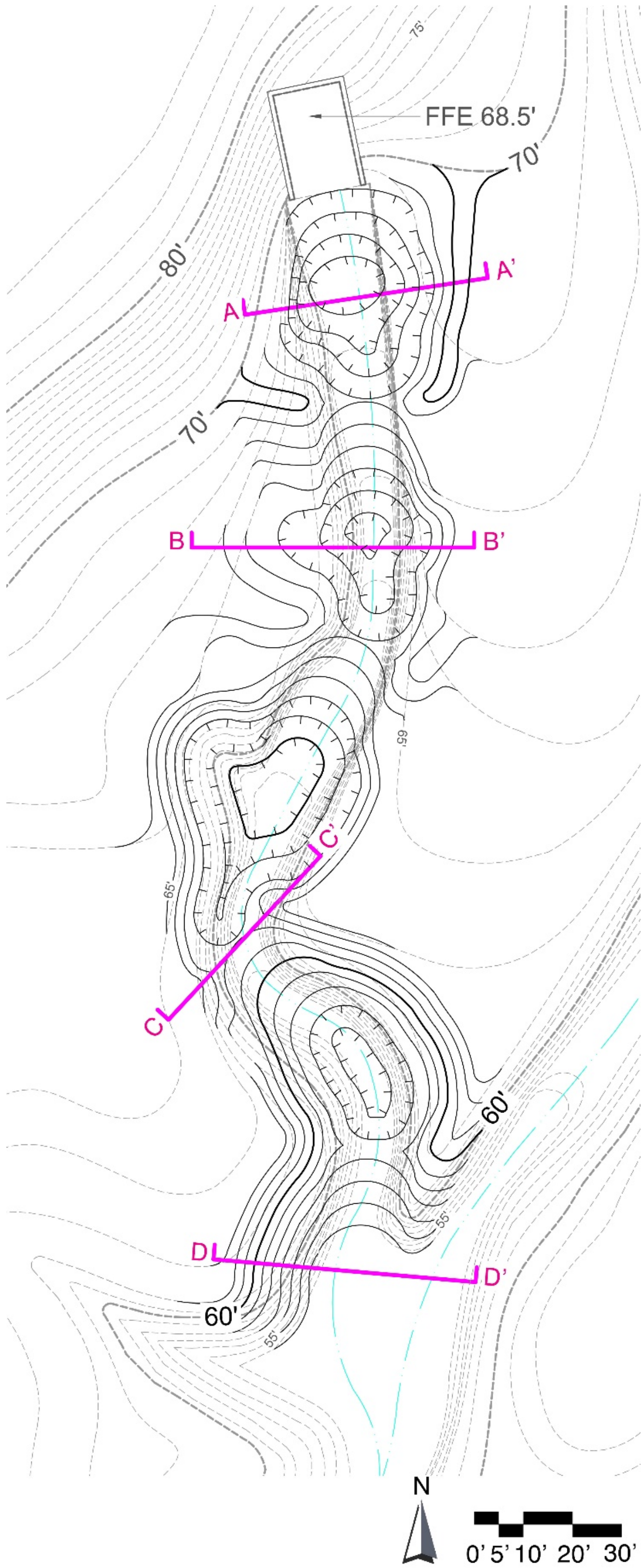


Figure 5.16: The one foot contour line topographic plan for the Parkdale High School RSC including section cut lines for the following sections

and pool depth selected. This embankment is necessary to hold the increased ponding during a 100-year storm event. From this plan and the profile the overall slope of the RSC is shown to be approximately 9.6%; while pool depths are 3 feet for pool 1, 2.5 feet for pool two and three and 1.5 feet for pool 4. Cascade heights do not exceed 6' and are shorter for the initial pool and the final cascade mimicking the Briers Mill Run RSC

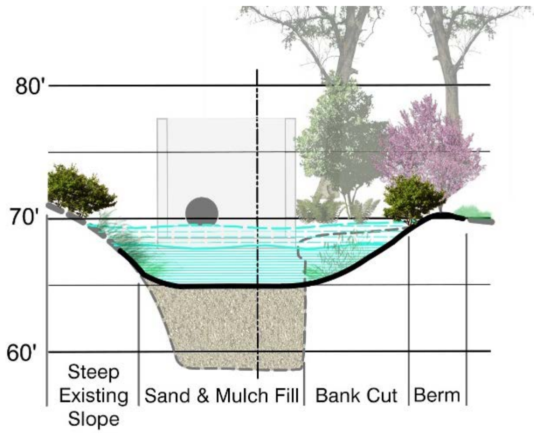


Figure 5.17: Section A-A' cut northward at STA 0+15 following the existing channel C.L.

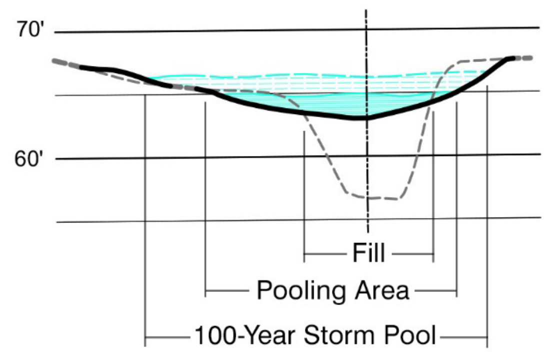


Figure 5.18: Section B-B' cut northward at STA 0+50 following the existing channel C.L.

The four sections in figure 5.17 to figure 5.20, in addition to the profile, assist in depicting fill, typical pooling depth (denoted by the solid cyan line) and the 100-year storm pooling depth (denoted by the dashed cyan line). For clarification: figure 5.19 denotes both of these areas. The first section of the set cuts through the first pool at STA 0+15 (along the existing C.L.), and looks north to the headwall showing general character of the planted and existing vegetation as well as areas of cut on the eastern bank and fill beneath the pool to a depth of approximately 6 feet.

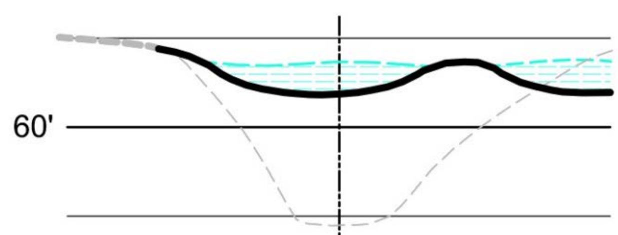


Figure 5.19: Section C-C' cut northward at STA 1+08 following the existing C.L. which cuts through the pool crest point

Figure 5.19 cuts perpendicularly through a weir and shows the typical sizing, which was calculated for earlier in this chapter.

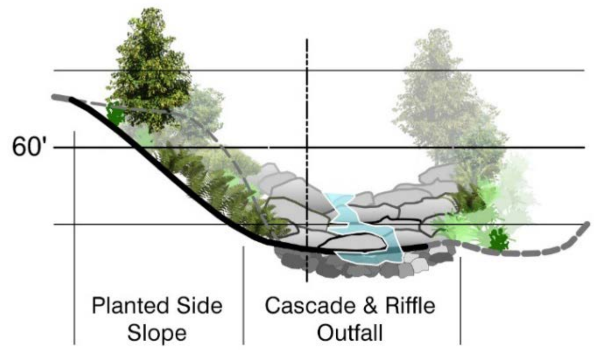


Figure 5.20: Section D-D' cut northward at STA 1+58 following the existing C.L. which cuts through the outfall riffle looking towards the final cascade

The final section (to the right) cuts through the final RSC tie out into the receiving channel. The section portrays the prescribed native shrubs, understory trees, grasses and fern in the area of the riffle and cascade outfall. Lastly, it depicts how the typical cascade will generally appear when constructed. Per the AACDG:

> The boulders found in [RSC systems should be sandstone] (e.g., bog iron, iron stone, ferracrete). Sandstone's porosity, as well as its ability to retain water, allows it to naturalize quickly, providing habitat for ferns, moss, and other organisms that persist in these systems.

Figure 5.21: An image of a sandstone boulder covered with moss and fern at a newly constructed RSC in East Washington D.C. in Fall 2016

The latter AACDG assertion is corroborated by the sandstone boulder covered with moss in figure 5.21. This boulder was placed less than a year prior to the photo being taken.

To preserve acidic PH levels throughout the system, limestone and cement-based stone also shall be prohibited. The cobbles in the riffle section preferably are prescribed to be 6" in diameter crushed

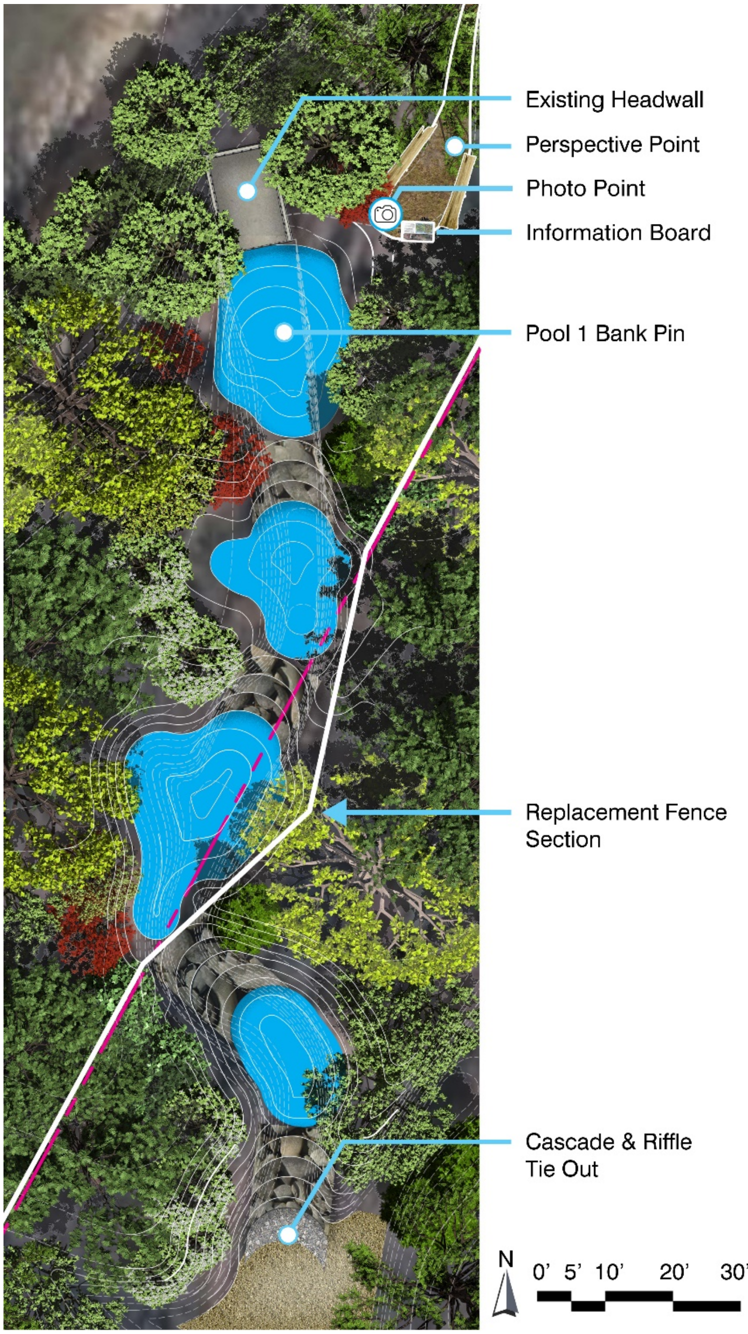


Figure 5.22: The illustrative plan for the Parkdale High School RSC

sandstone, as well and filled to a depth of a foot. The cascade boulders are prescribed to be 3-4x the size of the cobble, also being at least 2 feet in length, as specified in the AACDG. Fill underneath the pools and cascades should first be filled in with onsite cut material, and then the remainder filled with a sand and mulch mixture, 20% of which will be onsite mulched woody material.

The illustrative plan (to the left) and the accompanying perspective (on the following page) illustrate several design aspects. The plan proposes a path on the north east side which terminates at a teaching and viewing area. The viewing area is composed of repurposed logs for seating and an information board which will document before conditions for viewers as well as generally

Figure 5.23: A perspective from the teaching and viewing area next to the first pool and headwall (see "perspective point" in the illustrative plan)

explaining best management practice, stormwater and ecosystem principles. Other aspects included are a bank pin to assist in documenting sediment deposition in the first pool as well as the creation of a photo point as set forth in Chapter 5 of the EPA document "Monitoring and Evaluating Nonpoint Source Watershed Projects". The purpose and goal of the photo point and bank pin will be to include students and teachers in the documentation of change, erosion, performance and sediment deposition in the RSC system.

Plant Material

While RSC has its roots in the biomimicry of magnolia bogs; the planting material found in precedent designs were largely dissimilar. For instance Linnean Gully RSC was the only RSC visited to include the sweetbay magnolias for which magnolia bogs were named. Furthermore, Briers Mill Run planset specifications contain none of the species associated with magnolia bogs in literature reviewed

(Simmons Strong. 2003; National Capital Region Inventory and Monitoring Network, and Urban Ecology Research Learning Alliance, 2007). With that in mind, and with the scarcity of availability of magnolia bog species it is recommended that magnolia bog related species should be limited to those which can also be found in the document "Native Plants for Wildlife Habitat and Conservation Landscaping: Chesapeake Bay Watershed". Those plants are the sweetbay magnolia, smooth winterberry (*Ilex laevigata*) and highbush blueberry (*Vaccinium corymbosum*).

Other species recommended for areas around the RSC are native plants that are found within the Briers Mill Run RSC planset, and plant material that prefer acidic soils, moderately wet to wet conditions and partial shade to full shade. Some shrubs that satisfy these conditions are: American sycamore, willow oak (*Quercus phellos*), black gum, red maple, sassafras, spicebush, arrowood, inkberry (*Ilex glabra*) and winterberry (*Ilex verticillata*). All other planted vegetation should meet the aforementioned requirements.

CHAPTER 6: CONCLUSION

Design Performance

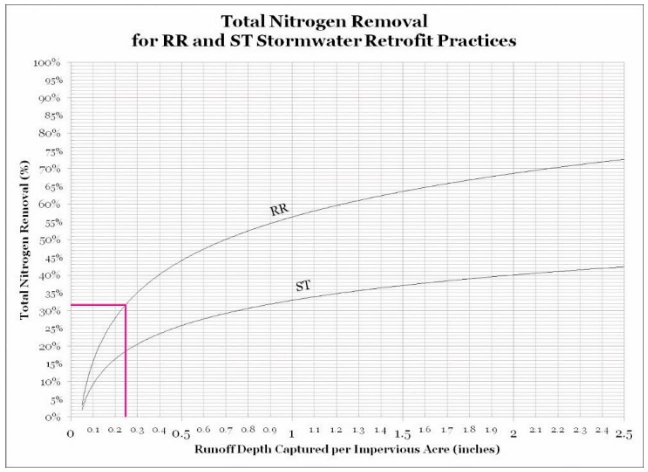


Figure 6.1: The total nitrogen removal curve table for the designed RSC

The Maryland Department of the Environment crediting for the Parkdale High School RSC was undertaken after design. As stated in chapter 2: RSC is considered to be a “Runoff Reduction” practice as a “stormwater retrofit practice” in Maryland (WQGIT, 2014). In order to determine Total Nitrogen (TN), Total Phosphorous (TP) and Total Suspended Solid (TSS) removal rates it is first necessary to determine the runoff volume treated using the equation:

$D_r = \frac{(RS)(12)}{IA}$ (WQGIT, 2012)

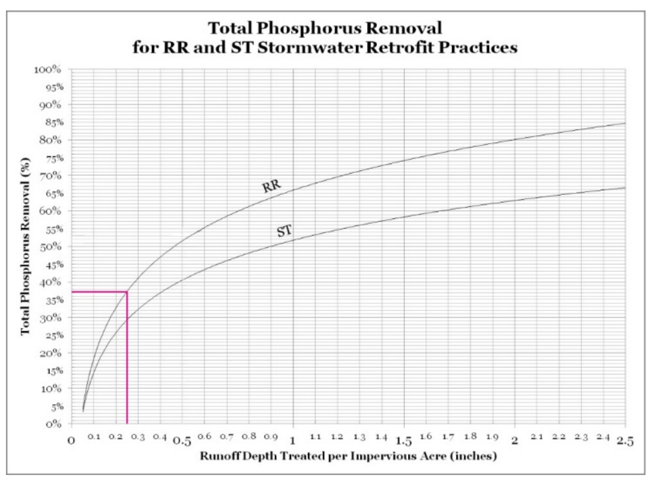


Figure 6.2: The total phosphorous removal curve table for the designed RSC

For the Parkdale High School RSC the runoff storage volume was found to be 1994.8 ft^3 from the void storage volume, and 2528.3 ft^3 from the above ground storage in the pools; which equated to 4523.1 ft^3 total. This was inputted into the above equation along with the values for the impervious cover of the catchment which produced:

$$0.24 = \frac{(4523.1)(12)}{((0.3)(17.2 \times 43{,}560))}$$

The Parkdale RSC was found to treat a runoff volume of .24" for the 17.2 acre site which equates to 32% TN, 37% TP and 40% TSS removal. This was found by the reduction curve tables in the document "Final Approved Report: Recommendations of the Expert Panel to Define Removal Rates for Urban Stormwater Retrofit Practices" and are shown in figure 6.1 to 6.3

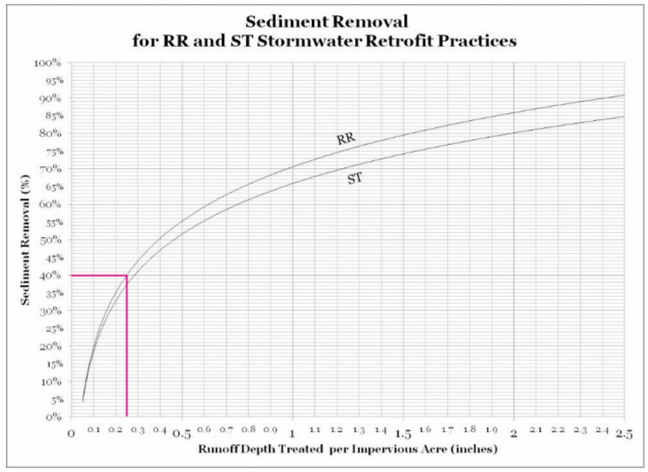


Figure 6.3: The TSS removal curve table for the designed RSC

Goal Performance

The creation of the Parkdale High School RSC included three primary goals: 1) remediate an outfall in the Washington D.C. Metropolitan area and design for the 100-year storm flow 2) treat and detain as much stormwater as possible 3) make RSC readily accessible to teachers and create opportunity for student involvement.

Goal 1: Remediate an Outfall in the Washington D.C. Metropolitan Area and Design for the 100-year Storm Flow

The first goal was achieved by the proposed implementation of a RSC at Parkdale High School which would stabilize all banks along the Outfield Channel and create a stable profile along the newly formed channel centerline. The first goal is further promoted by undertaking calculation of the 100-year storm peak flow through usage of the USDA Win TR55 stormwater modelling program, and then designing a parabolic weir that could conduct that predicted flow rate. A 12’ x 1.5’ weir was calculated to be satisfactory for conveying the 114.76 ft^3/sec peak flow. The design also conformed to a number of design guidelines of the AACDG and the Briers Mill Run RSC such as the utilization of maximum slopes of 1V:3H for unarmored slopes within pools and maximum slopes of 4V:5H outside of pools and cascades.

As explained in chapter 3, the RSC which served as the primary reference for the design of the Parkdale High School RSC had a partial blowout in the summer of 2017.

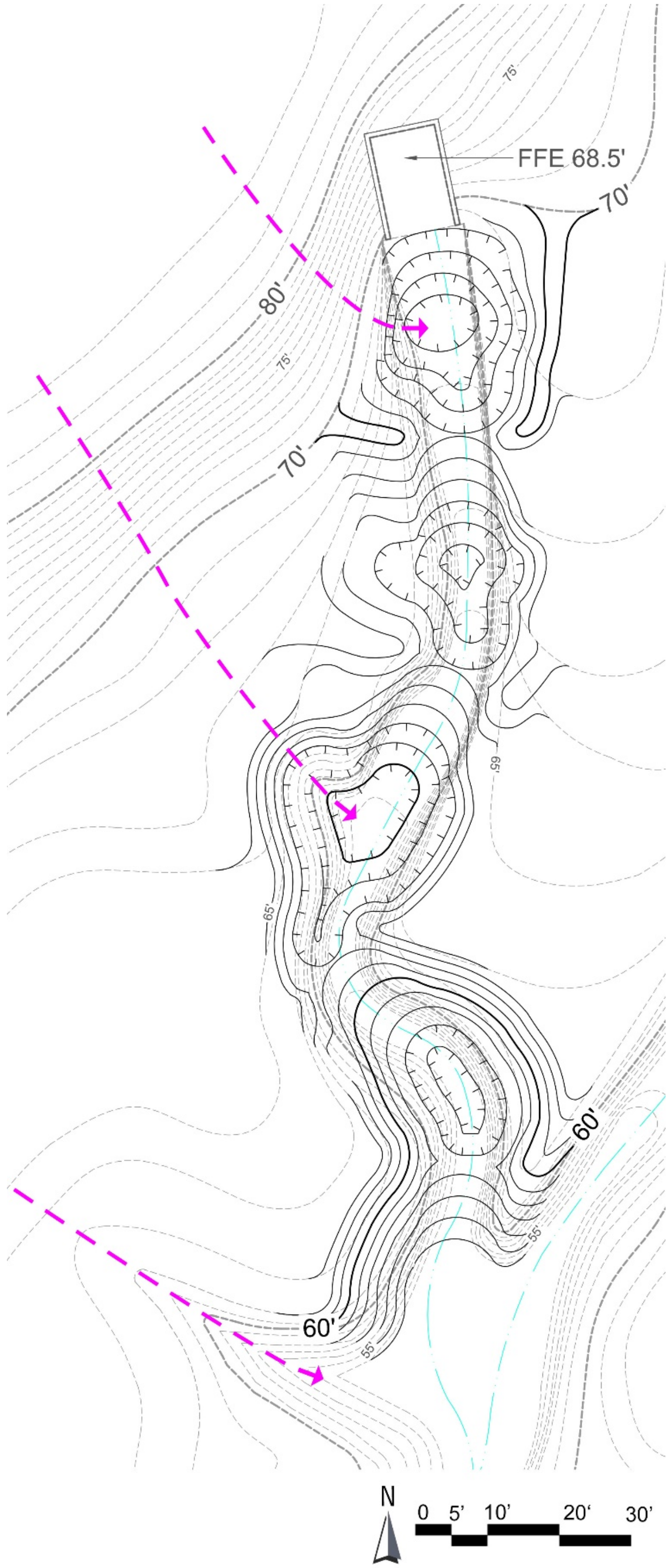


Figure 6.4: A topographic plan diagraming overland flow paths on the western side of the proposed RSC in order to avoid blowouts from overland flows

It was concluded that overland flow eroded one of the cascade embankments. Thus, it would be prudent to divert overland flow accordingly at the Parkdale High School proposed RSC.

It is possible for the proposed design that overland flow on the western side of the RSC could lead to similar issues, thus on the western side of the Outfield Channel creation of swales or flow paths that lead into the pools and away from the cascades would assist in assuring resilience to blowouts as depicted in figure 6.4. The eastern side of the Parkdale RSC has minimal overland flow and the drainage largely leads away from the RSC; however, extending the berm into the headwall would assist in assuring that overland flows are directed around the first pool.

Lastly, while slopes of the cascades of the proposed design conformed to heights and slopes of the Briers Mill Run RSC, it was suggested that having more gradual cascade slopes than the 30% slopes suggested may further increase resilience of the design via more stable pool embankments.

Goal 2: Treat and Detain as Much Stormwater as Possible

The second goal was achieved by maximizing detention volumes within ponding areas, and by maximizing the treatment volume in the seepage beds below the ponding areas. This treatment volume was measured to be 4532.1 cubic feet, as measured above, which would treat water from a runoff volume of $\approx$ ¼” from the 17.2 acre catchment.

Ideally to treat more of the stormwater in the Outfield Channel catchment than just that from a ¼” storm there are a number of good options in order to increase the runoff volume treated and generally to increase stormwater treatment and detention in the catchment. Options upstream of the RSC are depicted in figure 6.5. One option would be a replacement of the impervious concrete channel surrounding the track and field with a bioretention swale. Another option would be to replace parking bays in the parking lot on the western side of the catchment with pervious pavement. A third practical suggestion for this catchment is the creation of a large bioretention cell around the tennis court. A final suggestion would be to create areas of pervious pavement around the perimeter of the track at the base of the bleachers.

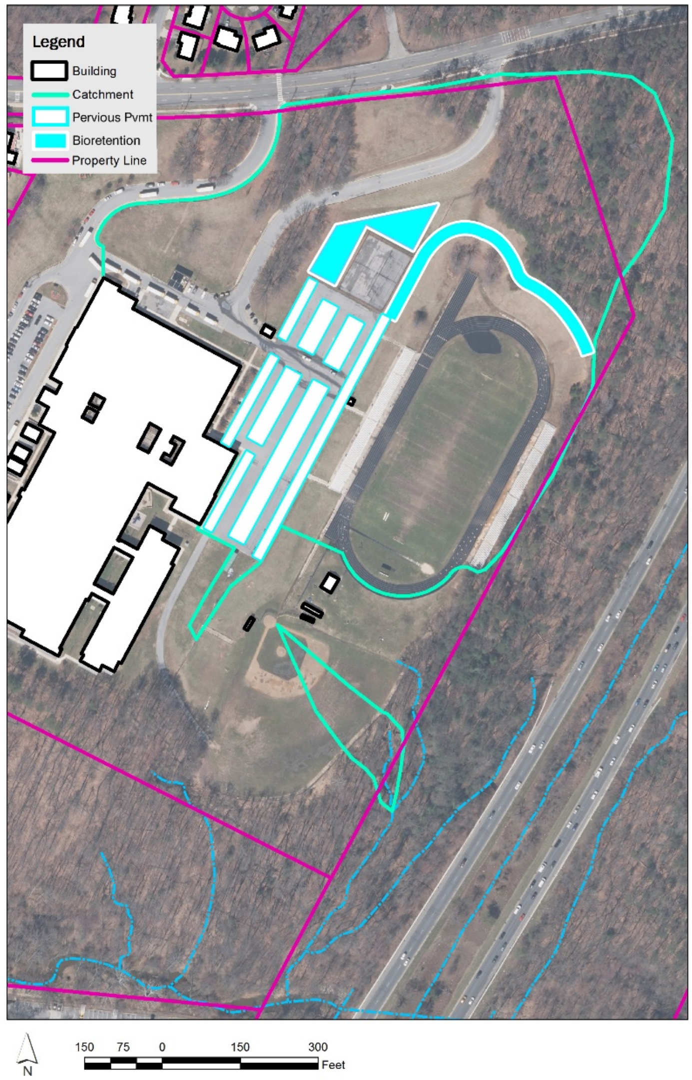


Figure 6.5: A map diagraming other potential BMPs to consider for achieving stormwater management goals

To reiterate, there is a lot more potential for RSC to assist in the treatment of stormwater from the Outfield Catchment than that suggested in the RSC design proposed. The receiving channel is almost three times the length of the Outfield Channel, and includes the entirety of the Outfield Channel's catchment. As stated before, the detention volume of the receiving channel is very likely three to five times larger than the detention volume of the Outfield Channel and there are also areas within the receiving channel that are actively eroding. Thus the receiving channel is a good option for treating a vast amount of stormwater and remediating channels that are actively eroding. That being said, it should be noted however, that the receiving channel is completely on NPS land and not on PGCPS land.

Goal 3: Make RSC Readily Accessible to Teachers and Create Opportunity for Student Involvement

The third goal was achieved foremost by the selection of a degraded channel to be remediated at Parkdale High School where the RSC would be partially on Prince George's County Public School Land. As said before, the RSC at Briers Mill Run does not have convenient access from Parkdale High School and would require a ten to fifteen minute bus trip to get to. Furthermore, Briers Mill Run RSC is gated from the public and would require extra coordination with the Anacostia Watershed Society to get access.

Other design aspects that assist in achieving this goal is the addition of a clear pathway from the track and baseball field which would terminate at a teaching and viewing area with a photo point and bank pin that would give students and teachers the opportunity to assist in visually documenting sediment deposition and geomorphological changes that occur to RSC overtime. Lastly, the third goal would be achieved by documenting conditions of the channel prior to construction of the RSC and teaching challenges in the Chesapeake Bay watershed.

Concluding Thoughts

RSC should be considered as one of several tools at the hands of designers and engineers. While RSC does address many stormwater challenges such as nutrient uptake, peak flow reduction and decreasing flow volumes (see Chapter2: RSC Measured Performance in Literature); it is not a catch-all stormwater management practice to solving all stormwater related concerns. One study suggests "[RSC or] enhancing infiltration and storage proximal to the channel head does not restore long term storage and stream base flow" (Fanelli et al., 2017).

A paramount limitation of RSC is that they typically cannot capture or detain/retain large volumes of stormwater from large catchment areas such as that on site or that at the Briers Mill Run RSC. To demonstrate: at Parkdale High School the 17.2 Acre catchment will produce approximately 127,000 cubic feet of stormwater during a one-year storm. Were the whole Outfield Channel simply turned into a detention pond with a dam at the outfall into the receiving channel, its above ground stormwater storage capacity would only be able to capture a little over an eighth of the stormwater. Were stormwater retention or detention the primary goal of the designer; stormwater retention or detention ponds will better address those goals. However, RSCs will in most cases detain more water than an average bioretention facility and raingarden due to the 3 foot deep pooling sections and significant void space in the filtering soil medium.

Appendix

A.1 Sections Derived from Site Survey

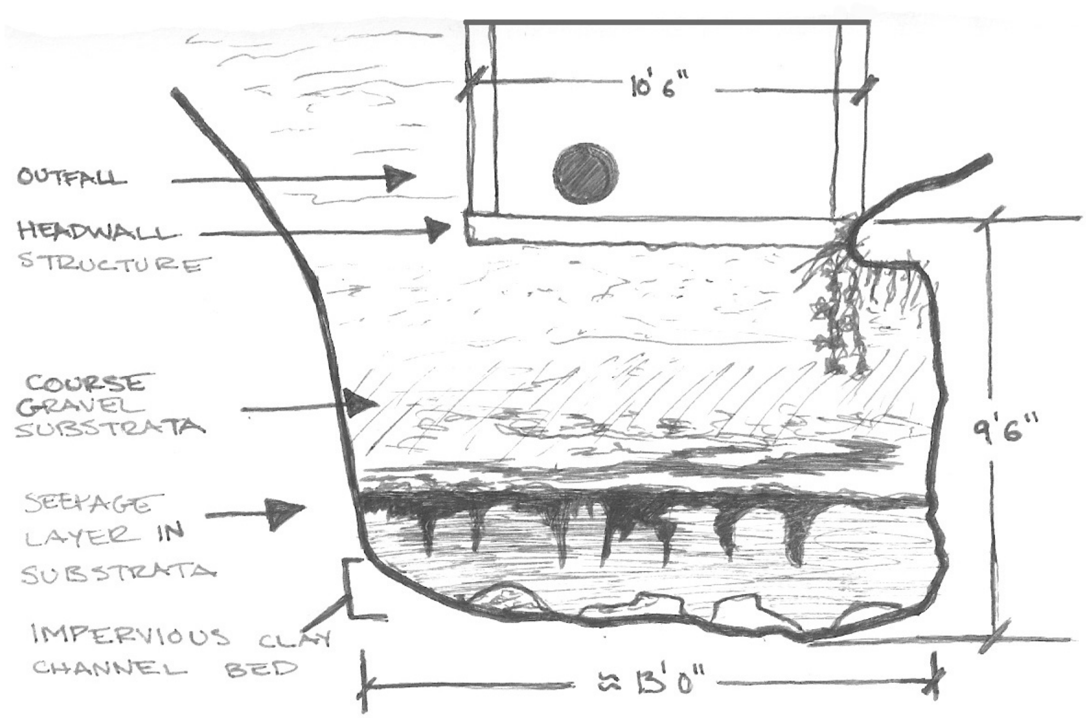


Figure A.1: A sketched northward facing section of station point 0+0

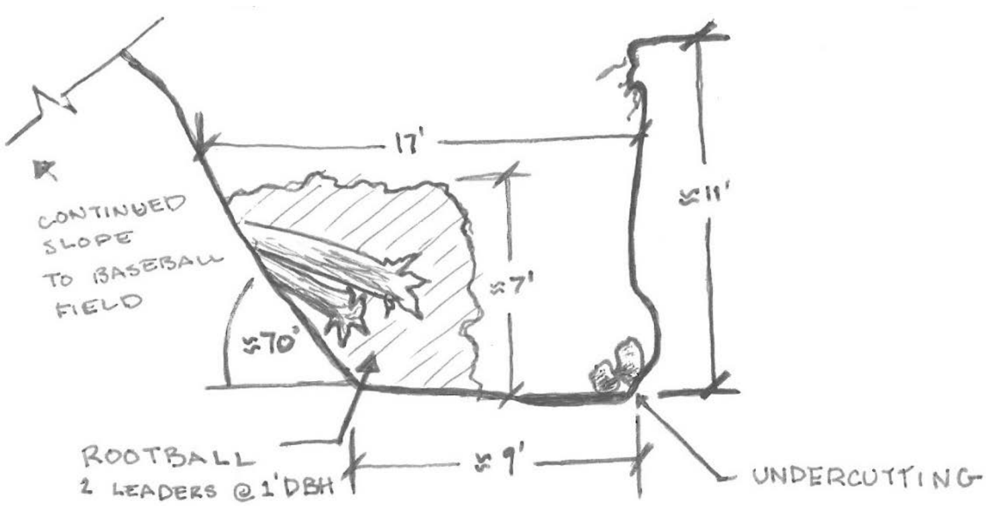


Figure A.2: A sketched northward facing section of station point 0+25

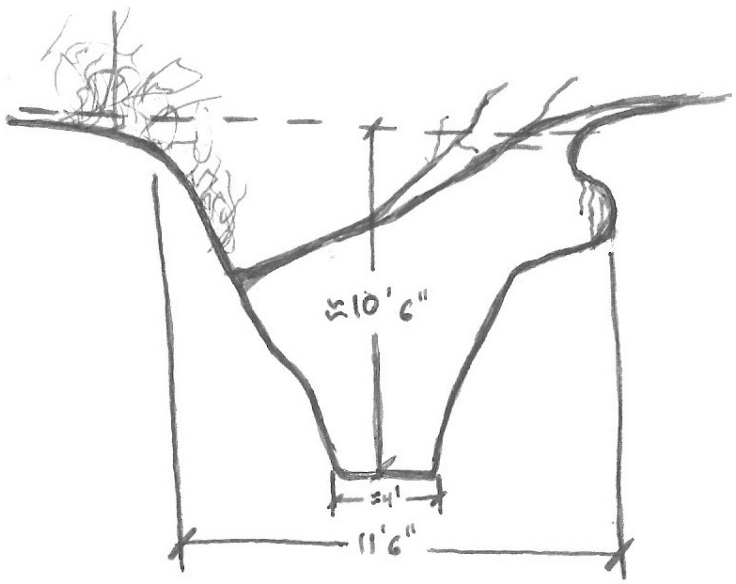


Figure A.3: A sketched northward facing section of station point 0+50

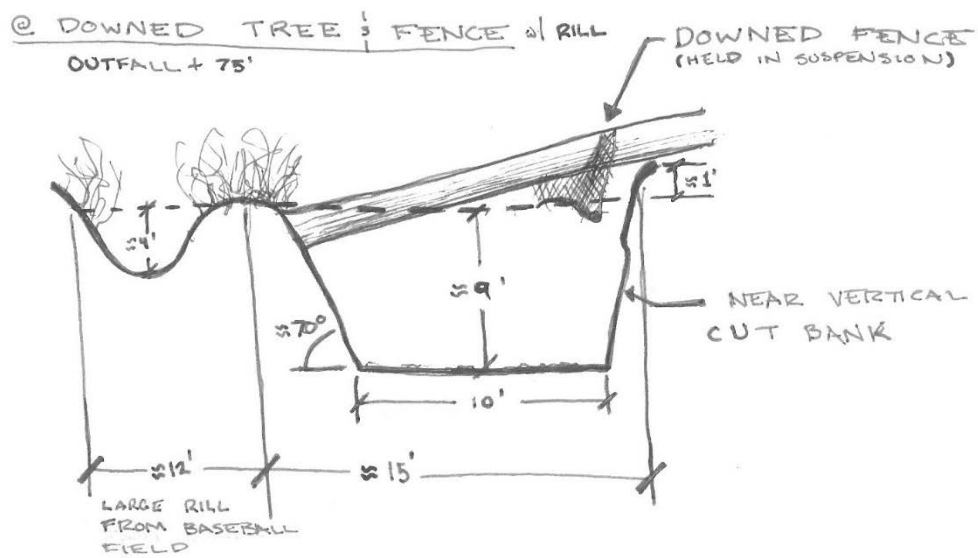


Figure A.4: A sketched northward facing section of station point 0+75

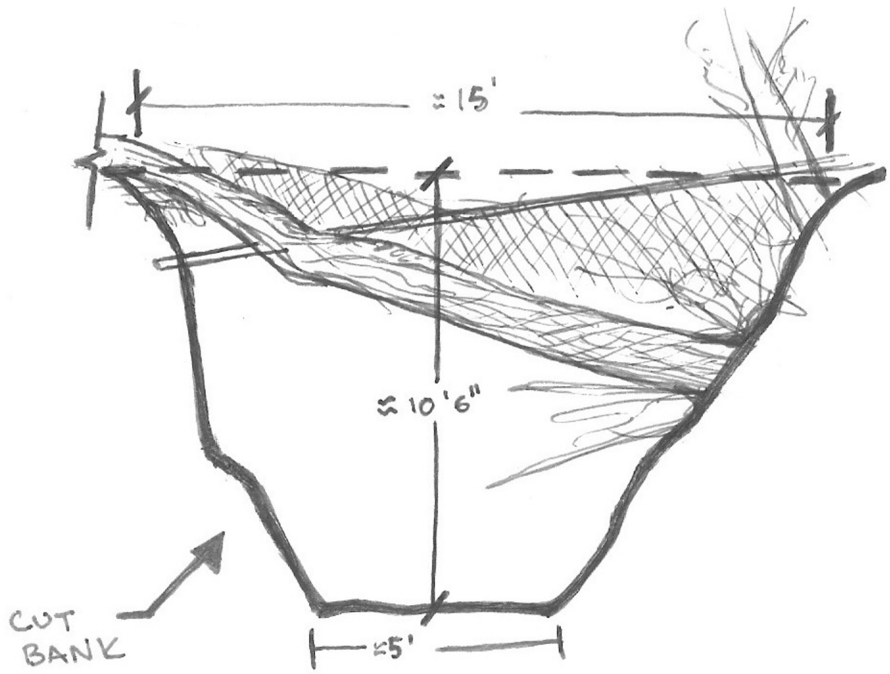


Figure A.5: A sketched northward facing section of station point 1+00

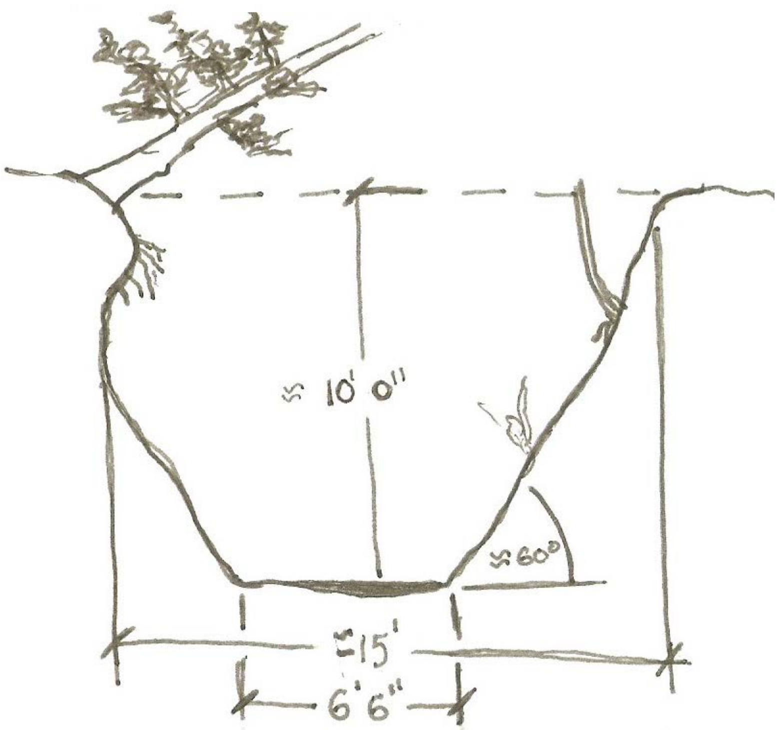


Figure A.6: A sketched northward facing section of station point 1+50

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