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Development of Multi-Catchment Rating Curves for Streams of Appalachian Mixed-Land-Use Watersheds: Preliminary Results

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**Development of Multi-Catchment Rating Curves for Streams of Appalachian Mixed-Land-
Use Watersheds: Preliminary Results**

Zachary Heck

Thesis submitted to the
faculty of the Davis College of Agriculture, Natural Resources and Design
at West Virginia University

in partial fulfillment of the requirements for the degree of

Master of Science in
Forestry

Approved by:

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Morgantown, West Virginia

2021

Keywords: Rating Curve; Streamflow; Stage; Cross-section

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ABSTRACT

Development of Multi-Catchment Rating Curves for Streamflow of Appalachian Mixed-Land-Use Watersheds: Preliminary Results

Zachary Heck

Anthropogenic activities can alter the quantity and quality of water. Traditional monitoring of streamflow involves measurements of stage (mm), or water height, and discharge (i.e., streamflow) (m^3s^{-1}) above a local datum. However, while stage is relatively easily monitored, continuous streamflow measurement is often impractical and prohibitively expensive. To address this challenge, rating curve equations can be developed to convert stage to flow. To establish a series of rating curves for flow estimations in Appalachia, an investigation was conducted in a representative urbanizing, mixed-land-use watershed in north-central West Virginia consisting of 21 nested stream gauge sites. At each site, stage was continuously recorded at 5-minute intervals using a Solinst Levelogger. Streamflow was observed using the cross-section method and an Acoustic Doppler Velocimeter (ADV). Stream cross-sections were conducted over a range of low to high flow events. A preliminary rating curve was developed for each of the 21 study sites, with sample sizes ranging from 21 to 53 per site. Preliminary results generated R^2 values ranging from 0.98 to 1. Three empirical streamflow models, Manning's equation, Chezy equation, and Dingman and Sharma equation, were used to estimate streamflow for comparison to observed flow (i.e., velocity-area method) at each site. Validation of the empirical models showed a significant difference ($\alpha=0.05$) between observed and modeled mean streamflow at sites 3, 4, 5, 8, 11, 15, 17, and 21. Even though only 8 sites showed significant differences between observed and modeled mean streamflow, the models inaccurately estimated streamflow during low flow events. While results from this study are preliminary, and not yet appropriate for stream flow estimates, work to date advances the understanding of stage versus discharge relationships in mixed-land-use watersheds of Appalachia. Ongoing research will result in a completed data set and regionally relevant rating curves.

The undersigned approve the thesis entitled

**Development of Multi-Catchment Rating Curves for Streams of Appalachian
Mixed-Land-Use Watersheds: Preliminary Results**

Presented by Zachary Heck,

as partial fulfillment to the requirement of the degree of M.S. of Forestry

and hereby certify that, in their opinion, it is worthy of acceptance

Dr. Jason A. Hubbart (Advisor)

Dr. Kirsten Stephan

Dr. Elliot Kellner

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CHAPTER 1:

INTRODUCTION

Background

Anthropogenic activities can impact the quality and quantity of water (Erwin and Hamilton 2002). For example, anthropogenic alterations to terrestrial landscape management practices (e.g., urbanization) were shown to disrupt natural stream geomorphological evolution, thereby altering stream ecological habitat and suspended sediment regimes (Sunde et al. 2018; Erwin and Hamilton 2002). Urban development often includes increased impervious surface area that can reduce infiltration, increase runoff (Sunde et al. 2018; Arnold and Gibbons 1996), affect streamflow volume and timing, baseflow, and contaminant transport processes (Sunde et al. 2018; Pappas et al. 2007). The changes caused by the introduction of impervious surfaces can lead to an increase in stream velocity resulting in channel incision and mass wasting (Kellner and Hubbard 2019; Leopold 1968), and subsequent sedimentation increases (Borah and Bera 2004). For example, previous studies showed that as little as 8-13% of total urban land-use is needed to significantly impact streamflow and bank erosion (Zeiger and Hubbard 2019; Zeiger and Hubbard 2018; Walsh et al. 2012).

Without accurate stream flow estimates, it is challenging to confidently quantify flow-related changes/impacts due to anthropogenic activities and in-situ changes in pollutant loading. Some of the original methods for estimating streamflow included the float method and the bucket and stopwatch method (Michuad and Wierenga 2005). To use the float method (Figure 1), the cross-sectional area of the stream channel needs to be calculated. After the cross-sectional area is calculated, an 8 to 30 m long section of the channel is measured and marked with a marker on

either end. The length used, greatly depends upon the velocity of the water (the higher the velocity, the greater the distance needs to be) (Michuad and Wierenga 2005). By using the average time it takes for an object to travel between point A and B (Figure 1), velocity can be estimated. Then by multiplying the velocity by the cross-sectional area, streamflow can be estimated (Michuad and Wierenga 2005). The bucket and stopwatch method is commonly used in stream channels with small waterfalls or v-notch weirs. Streamflow is calculated by recording the amount of time it takes for a bucket of known volume to fill up (Michuad and Wierenga 2005). Both of these techniques are replicated several times during one collecting event, and then the streamflow measurements are averaged (Michuad and Wierenga 2005).

Figure 1. A representation of the float method utilized to measure streamflow.

Other means for collecting streamflow have been developed, including the use of current meters (USGS 2019). Several different types of current meters are available, including rotating-

element mechanical meters and acoustic doppler velocimeters (ADV) (Turnipseed and Sauer 2010; Rehmel 2007; Buchanan and Somers 1969). Historically, the United States Geological Survey (USGS) has used the Price AA mechanical current meters to collect streamflow measurements (USGS 2019; Turnipseed and Sauer 2010). The Price AA can be used in velocities between 0.06 and 3.66 m/s, and depths greater than 0.38 m (Turnipseed and Sauer 2010; Buchanan and Somers 1969). For gauging sites with low velocities, the Price pygmy, a variation of the Price AA, is often used (Turnipseed and Sauer 2010). The Price pygmy is a scaled down version of the Price AA, that can measure stream velocity between 0.06 and 0.12 m/s, and depths between 0.09 and 0.5 m (Turnipseed and Sauer 2010). Both current meters are designed to attach to a top-setting wading rod to facilitate streamflow measurements in wadable streams (USGS 2019; Buchanan and Somers 1969). However, the Price AA can also measure stream velocity in deeper water by attaching it to a cable and reel system (USGS 2019).

In the early 2000s, USGS began using ADV[®] current meters, as replacements for the Price AA mechanical current meter, due to being more accurate at low flow (Rehmel 2007; Sontek 2003). Unlike the Price AA and Price Pygmy, that use velocity to rotate mechanical parts, ADV[®], such as the Sontek Flowtracker[®] and the more recent Flowtracker 2[®], measure velocity by sensing the velocity phase change of light reflected from suspended particles, by using the Doppler effect (Rehmel 2007; Sontek 2003). Similar to the Price AA and the Pygmy Price, the Sontek Flowtracker[®] and Flowtracker 2[®] are most effective when used on a top-setting wading rod for measurements (USGS 2019; Turnipseed and Sauer 2010, Sontek 2003).

The use of a wading rod is the preferred method when collecting streamflow measurements using a current meter. This is due to the advantages that field personnel have when selecting the best location to conduct a velocity reading (Turnipseed and Sauer 2010). Top-

setting wading rods comprise a stationary rod that has a foot on the bottom and an adjustable rod that holds the sensor for the current meter. The top-setting wading rod is generally preferred among wading rod types due to the convenience of setting the current meter sensor to the proper water depth without the need for the operator to place their hands in the water (Buchanan and Somers 1969). With the stationary rod on the streambed, the adjustable rod is moved up and down depending upon the water depth, this adjustment allows for velocity to be recorded at the appropriate depth (Sontek 2003; Buchanan and Somers 1969). When using current meters on a top-setting wading rod (mechanical current-meters or ADV), velocity is usually measured at three different point settings: the single point method (0.6), the two-point method (0.2 and 0.8), and the three-point method (0.2, 0.6, and 0.8). These numbers represent the fractional distance from the water surface (WSC 2015). The 0.6 method (60%) is generally used when the water depth is below 0.5 m, where it is understood that the mean velocity in the water column is found at this location (Sontek 2003; WSC 2015; Herschy 1995). The 0.2 (20%) and 0.8 (80%) method is generally used when the water depth is greater than 0.5 m. Using this method, velocity is measured at both points then averaged to determine the average velocity for the water column (Sontek 2003; Herschy 1995). The 0.2, 0.6, and 0.8 method is a combination of the other two methods. This method is generally used when the stream channel is covered in aquatic vegetation or contain large rocks. By using this the latter method, any accuracy errors due to turbulence or obstructions can be avoided (WSC 2015). The only detriment to this method is the amount of time required to collect all three velocity points, which may not be feasible during storm events where stream stage may rise and fall quickly (Herschy 1995).

By combining the point settings while using a wading rod and the velocity-area method, streamflow can be measured within a stream cross-section. The velocity-area method is one of

the most widely used methods for measuring streamflow (m^3/s) (USGS 2019; Turnipseed and Sauer 2010). Streamflow, using this method, is calculated by dividing the channel into segments or subsections. Within each segment or subsection, water depth and velocity are measured. Velocity is averaged then multiplied by the cross-section area to give streamflow. The number of segments within a stream channel greatly depends upon channel width (i.e., the wider the channel, the more segments) (USGS 2019; Turnipseed and Sauer 2010).

However, continuously monitoring streamflow can be costly in terms of instrumentation and labor, and the method is potentially dangerous for field personnel. To address these issues and reduce the need for streamflow monitoring in all places (an infeasible proposition), rating curves can be developed that are regionally relevant (i.e., transferrable) and reflect many different land-use practices. A rating curve is a graphical representation of the relationship between stage and discharge (i.e., streamflow) (USGS 2019). The graphical representation represents a mathematical model of the data, that can be applied to stage data (water depth) to estimate streamflow.

Traditionally, rating curves have been constructed using the power-law function (Equation 1) or 2nd/3rd degree polynomial functions (Equation 2 and 3, respectively) (Phillips 2009; Sivapragasam and Muttil 2005).

Power-law

$$Q = c(h - a)^n \quad (1)$$

where Q represents streamflow, h represents stage, and c , a , and n are constants that are determined using site specific observations of streamflow (Q) and stage (h). The constant a represents stage when streamflow is zero (Sivapragasam and Muttil 2005). Since a is an inferred

constant from collected data (streamflow and stage), these rating curves are generated for sites that have a stable stream channel, such as weirs or other manmade channels (Phillips 2009; Sivapragasam and Muttill 2005).

Polynomial Method

$$Q = c(h - a)^2 + b(h - a) + d \quad (2)$$

$$Q = c(h - a)^3 + b(h - a)^2 + d(h - a) + e \quad (3)$$

where Q represents streamflow, h represents stage, and a , b , c , d , and e are constants that are determined using the observed data of h and Q . The constant a represents stage when streamflow is zero (Sivapragasam and Muttill 2005). Since a is an inferred constant from collected data (streamflow and stage), these rating curves are generated for sites that have a stable stream channel (Phillips 2009; Sivapragasam and Muttill 2005; Fenton 2001). Once a well-developed rating curve is created, future streamflow can be estimated using stage measurements at a gauging site in the original study watershed or in other physiographically and climatically comparable watersheds (i.e., is transferrable) (USGS 2019; Ayele 2017; Pan et al. 2016; Bouska and Paukert 2010; Fenton 2001).

In cases where observed monitoring of stream stage and flow are lacking, less reliable yet still critically useful (empirical) methods are employed to improve confidence in land-use / land management decisions. These methods utilize a hybrid approach by using hydrologic models that require the collection of site-specific characteristics, but not the labor-intensive necessity of collecting cross-sections. The channel morphology measurements needed to calculate streamflow using this approach include channel width and depth, slope, wetted width, and streambed roughness (n) (Chow 1959).

For example, the Manning's equation (Equation 4), the Chezy equation (Equation 5 and Equation 6), and the Dingman and Sharma equation (Equation 7) are commonly used streamflow models that utilize a hybrid approach, due to the need of site-specific measurements (Dingman 2008; Sivapragasam and Muttill 2005; Dingman and Sharma 1997; Rantz et al. 1982b).

Manning's Equation

$$Q = VA = \left(\frac{1.49}{n}\right) AR^{\frac{2}{3}} \sqrt{S} \quad (4)$$

where Q represents streamflow, V represents velocity, and A represents flow area. This is then further broken down so that n represents Manning's coefficient, A represents flow area, R represents hydraulic radius, and S represents channel slope.

Chezy Equation

$$Q = C A_c R_H^{\frac{1}{2}} S^{\frac{1}{2}} \quad (5)$$

where Q represents streamflow, C is the Chezy C coefficient (Equation 5), A_c represents the wetted channel area, R_H represents hydraulic radius, and S represents slope.

$$C = \left(\frac{1.49}{n}\right) R_H^{\frac{1}{6}} \quad (6)$$

where n is Manning's coefficient of roughness and R_H represents hydraulic radius.

Dingman and Sharma Equation

$$Q = 1.564 A^{1.173} Y^{0.400} S^{-0.056(\log(S))} \quad (7)$$

where Q is streamflow (m^3/s), A is the average cross-sectional area (m^2), Y is average depth (m), and S is the slope of the water surface.

Over or underestimation of streamflow using empirical models is common due to assigning incorrect values to constants within the equations, especially in mountainous regions. For example, errors in streamflow estimation using the Manning's and Chezy equation are often due to assigning the incorrect value for Manning's n coefficient of roughness. Many techniques for estimating n have been developed in lowland rivers that are characterized by shallow slopes and streambed particle sizes for small streams (Marcus 1992; Jarrett 1984; Bathurst 1978). There is therefore a need for advancing rating curve development in mountainous regions such as the Appalachians of eastern North America. The Appalachian region is characterized by physiographic complexity that can further confound watershed hydrologic processes and development of reliable rating curves (Hubbart et al. 2019; Hubbart 2011). Further, much of the region lacks reliable streamflow data that can be used to develop regionally relevant rating curves. There is therefore a need for observed streamflow and development of accurate rating curves for Appalachian streams and rivers that reflect the terrain and land-use practices and are therefore transferrable throughout the region.

Objectives

The overarching objective of this research was to develop a series of rating curve equations for several mixed-land-use catchments in a representative Appalachian mixed-land-use watershed. Additionally, select empirical flow estimation models, were validated using the observed streamflow measurements. Study results advance understanding of the stage and discharge relationship for mixed-land-use watersheds in mountainous terrain of the Appalachian region of the United States and similar physiographic regions globally.

Hypotheses

This research tested the following hypotheses related to the objectives:

1. Validation of developed rating curves based on observed and modeled data.

H_0 : There is no difference between observed and modeled data.

H_a : Developed rating curves differ between observed and modeled data.

2. Validation of select empirical flow estimations for observed streamflow data.

H_0 : Selected empirical flow models showed no significant difference from the observed streamflow data.

H_a : Selected empirical flow models showed significant differences from the observed streamflow data.

METHODS

Study Site Description

This research was conducted in the West Run Watershed (WRW), located in north-central West Virginia (Figure 2). The WRW is a 2,330-ha (5,760-ac), mixed-land-use watershed in Morgantown, WV. Located in north-central West Virginia in the Central Allegheny Plateau, the area is underlain by interbedded shale, siltstone, sandstone, coal, and limestone (Wright et al. 1982). Along the channels, there are numerous Pennsylvanian (Upper Carboniferous) rock outcroppings (Wright et al. 1982; West Virginia Geological and Economic Survey 1913). Within these rock formations are several coal seams, the Upper Kittanning coal and the Pittsburgh coal. The older formations, including the Upper Kittanning, are present at the Monongahela River's confluence. The Monongahela series, a younger formation, is present in the watershed headwaters and contains the Pittsburgh coal seam (West Virginia Geological and Economic Survey 1913). The Pittsburgh coal seam, which has an average thickness of 2.1 m, has served as an essential resource for the Morgantown area and surrounding counties. The Pittsburgh coal seam and other coals seams have provided a valuable economic resource for the region since the early 1800s (Laing 1966). Much of the mining in WRW involved underground mining between 1930 and 1950 and had stopped before the 1977 Surface Mine Control and Reclamation Act (West Virginia Geological and Economical Survey 2009). Using a geologic overlay developed by the West Virginia Geological and Economic Survey in ArcGIS, an assessment of the surface geology distribution in the WRW was generated in Figure 3, and a breakdown of the units found in each group in Table 3.

The topography of WRW is predominantly rolling; elevation in WRW ranges from approximately 240–420 m, and slope generally ranges from 3–30 percent, with some areas of short steep slopes greater than 50 percent. Soils of the uplands are formed in residual material

weathered from the underlying sedimentary rocks, while soils of the foot slopes and in heads of drainageways are formed in colluvial materials that have eroded from the residual soils and parent materials (Wright et al. 1982). On the terraces and floodplains that are adjacent to West Run and its tributaries, soils formed in locally-derived alluvial materials eroded from the surrounding soils (Wright et al. 1982). Using the most recent Soil Survey Geographic Database (SSURGO) in ArcGIS, an assessment of the soil orders and textures was generated in Figures 4 and 5.

The climate in north-central West Virginia is characterized by strong seasonal frontal storm systems that deposit most precipitation during the spring and summer months (Horne and Hubbard 2020; Kutta and Hubbard 2019a; Kutta and Hubbard 2019b). The wettest month of the year is July, with the average precipitation of 11.7 cm. West Virginia does not experience a dry season; however, the driest month of the year is February, with an average precipitation of 6.6 cm (Petersen and Hubbard 2020b; Peel et al. 2007). The average yearly precipitation in Morgantown, West Virginia is approximately 110 cm, with previous studies showing a significant ($p=0.01$) increases by 2.2% over the past 111 years in the Appalachian region (Kutta and Hubbard 2019b). The temperatures in West Virginia are seasonal. The summers are generally hot and humid, with average monthly temperatures $> 22^{\circ}\text{C}$. The warmest month is July, with the average daily temperature of 23°C . The winters are cold ($< 0^{\circ}\text{C}$), with the coldest month being February with average daily temperatures of -0.4°C (Petersen and Hubbard 2020b; Arguez 2010). The overall average annual temperature (between 1906-2016) ranged from 4.9°C to 18°C , with an annual average temperature of approximately 11.45°C (Kutta and Hubbard 2018).

West Run Creek is a tributary of the Monongahela River. WRW is a mixed-land-use watershed encompassing 23 km² of the northern part of Morgantown, West Virginia. West Run Creek is characterized by moderately entrenched channels with relatively narrow floodplains. The watershed headwaters have an average slope of approximately 1.1% that gradually becomes less than 1% at the river's mouth. Due to its low gradient and narrow channels, the watershed contains no dams or navigable waterways. Using the 2016 National Land Cover Dataset (NLCD) in ArcGIS, an assessment of the land-use and cover was generated. For this work, the 16 land-use and land cover (LULC) types provided in the 2016 NLCD were categorized into one of four categories: forested, agriculture, mixed development, and open water (Figure 2 and Table 1). While most of the watershed is undergoing development, sections of the watershed remain relatively undeveloped with minimal infrastructure (e.g., buildings, paved surfaces). Several undeveloped portions of the watershed are owned by West Virginia University (WVU) and are used as educational resources, experimental farms, and forests (Horne and Hubbart 2020, Petersen and Hubbart 2020a, Petersen and Hubbart 2020b, Petersen and Hubbart 2020c, Petersen et al. 2018).

Table 1. Categorical breakdown of the four-primary land-use types used in the WRW using the 2016 NLCD.

Primary Land-Use Types	Included Land-Uses
Forested	Mine Grass, Forest, Small Stream Riparian Habitats, Mixed Mesophotic Forest, Dry Mesic Oak Forest, and Dry Pine Forests
Agriculture	Low Vegetation, Hay Pasture, and Cultivated Crops
Mixed Development	Mixed Development, Barren, Impervious, and Roads
Open Water	Water, River Flood Plains, and Wetlands PEM

Land-use and Land Cover

For this research, a paired and scale-nested experimental watershed design (Petersen and Hubbart 2020b; Hubbart et al. 2019; Hubbart et al. 2007; Loftis et al. 2001) was implemented consisting of 21 study sites (i.e., gauging sites) (Figure 2). The study design includes numerous stream stage monitoring locations along the West Run Creek channel and in several 1st and 2nd order tributaries within the watershed. Sites 3, 4, 6, 10, 13, 18, 19, and 21 are located along West Run Creek (main tributary), while sites 1, 2, 5, 7-9, 11, 12, 14-17, and 20 are located on 1st and 2nd order tributaries of West Run creek.

Based on the four land-use classifications designated for this study, WRW consists of 42.7% forested, 19.4% agriculture, 37.7% mixed development, and 0.2% open water. Within the sub-watersheds in WRW, sites 2-10, 12-14, 16-19, and 21 have the dominant land-use type of forested, and site 11 has a dominant land-use of agricultural and forested. Remaining study sites (1, 15, and 20) have the dominant land-use type of mixed development (Table 2).

Table 2. Distribution of primary land-use practices in the West Run Watershed, Morgantown, West Virginia, U.S.A. Also, including the longitude and latitude coordinates of each monitoring site.

Site	Location	Forest (%)	Ag (%)	Mixed Developed (%)	Open Water (%)
1	N39° 38.546'	8.1	38.1	53.2	0.6
	W79° 53.836'				
2	N39° 38.528'	74.2	12.2	13.6	0
	W79° 53.843'				
3	N39° 38.539'	61.3	16.2	22.4	0.2
	W79° 53.857'				
4	N39° 38.670'	59.0	14.9	25.9	0.2
	W79° 54.278'				
5	N39° 38.665'	51.1	25.5	23.4	0
	W79° 54.325'				
6	N39° 38.997'	58.7	17.3	23.9	0.1
	W79° 54.755'				
7	N39° 39.189'	54.9	28.6	16.3	0.2
	W79° 54.181'				
8	N39° 39.172'	52.4	16.5	30.8	0.3
	W79° 54.222'				
9	N39° 39.059'	52.8	19.3	27.6	0.3
	W79° 54.798'				
10	N39° 39.072'	56.5	18.4	24.9	0.2
	W79° 54.808'				
11	N39° 39.310'	39.2	41.9	18.2	0.7
	W79° 55.067'				
12	N39° 39.296'	34.5	33.7	31.8	0
	W79° 55.829'				
13	N39° 39.443'	47.2	25.8	26.8	0.2
	W79° 55.925'				
14	N39° 39.545'	56.9	26.4	16.2	0.5
	W79° 55.873'				
15	N39° 39.678'	19.4	10.3	70.3	0
	W79° 56.268'				
16	N39° 39.844'	35.2	58.7	5.4	0.7
	W79° 56.300'				
17	N39° 39.922'	85.8	9.4	4.8	0
	W79° 56.410'				
18	N39° 39.889'	48.9	24.9	26.0	0.2
	W79° 56.467'				
19	N39° 40.278'	47.9	22.5	29.5	0.1
	W79° 58.170'				
20	N39° 40.254'	6.6	4.2	89.2	0
	W79° 58.170'				
21	N39° 40.671'	42.2	19.5	38.1	0.2
	W79° 58.215'				
WRW		42.7	19.4	37.7	0.2

Figure 2. Map of experimental study design comprising 21 monitoring sites, with land-use and land cover, in West Run Watershed (WRW), Morgantown, West Virginia, U.S.A. Note: Legend colors appear slightly lighter in comparison to map, this is due to a hillside overlay on the map to give elevation contrast.

Figure 3. Surface geology in the West Run Watershed (WRW), Morgantown, West Virginia, U.S.A. Map units represent the following: Pnc- Pennsylvanian shale, Pnm- Pennsylvanian sandstone, and Qal- Quaternary alluvium (Table 3). Note: Legend colors appear slightly lighter in comparison to map, this is due to a hillside overlay on the map to give elevation contrast.

Table 3. Geologic units present in the West Run Watershed, Morgantown, West Virginia, U.S.A.

Map Unit	Period	Rock Type	Formations	Coal Formations
Pnc	Pennsylvanian	Shale	Cassleman, Glenshaw	Elk Lick, Bakerstown, Mahoning
Pnm	Pennsylvanian	Sandstone	Uniontown, Pittsburgh	Waynesburg, Uniontown, Sewickley, Redstone, Pittsburgh
Qal	Quaternary	Alluvium

Figure 4. Soil textures in the West Run Watershed (WRW), Morgantown, West Virginia, U.S.A. Soil data from the most recent Soil Survey Geographic Database (SSURGO), 2011. Note: Legend colors appear slightly lighter in comparison to map, this is due to a hillside overlay on the map to give elevation contrast.

Figure 5. Soil orders found in the West Run Watershed (WRW), Morgantown, West Virginia, U.S.A. Soil data from the Soil Survey Geographic Database (SSURGO), 2011. Note: Legend colors appear slightly lighter in comparison to map, this is due to a hillside overlay on the map to give elevation contrast.

Data Collection

Stage Data

Each of the 21 monitoring sites were instrumented to monitor stage (cm) at 5-minute intervals for the duration of the study period 2018-2021 using Solinst® Levellogger Gold or Levellogger Edge pressure transducers installed in two-inch polyvinyl chloride (PVC) stilling wells. Solinst® Levelloggers measure the absolute pressure, which includes water pressure and atmospheric pressure combined (Solinst 2018). To compensate for atmospheric pressure, a Solinst® Barologger Gold/Edge, monitoring atmospheric pressure at 5-minute intervals, was installed at Site 13, due to being a central location within the watershed. To ensure the accuracy of stage recorded, the stilling wells were flushed of sediment periodically and freed of any sediment around the housing. Additionally, stilling well off-sets (distance between bottom of stilling well and streambed) were recorded once a year to guarantee recorded stage included the entire water column, then added to the stage during data processing (Table 4). The instruments used to monitor stage were replaced once during this study due to the age of previous sensors and the risk of sensor drift or failure.

Table 4. Accuracy, resolution, and timing of the Solinst[®] products used during this study in the West Run Watershed, Morgantown, West Virginia, U.S.A.

Instrumentation	Instrument Measurement	Time Used	Full Scale (FS)	Accuracy	Resolution
Levellogger Gold	Water Depth	Jan. 2018 to Feb. 2020	5 m	±0.3 cm	0.05% FS
Levellogger Junior Edge	Water Depth	Feb. 2020 to Dec. 2021	5 m	±0.6 cm	0.02% FS
Barologger Gold	Atmospheric Pressure	Jan. 2018 to Feb. 2020	Air Only	±0.1 cm	0.05% FS
Barologger Edge	Atmospheric Pressure	Feb. 2020 to Dec. 2021	Air Only	±0.05 kPa	0.002% FS

Streamflow Measurement

Streamflow was measured using the Sontek Flowtracker 2[®] at all 21 study sites in the WRW following the cross-section and velocity-area method (Figure 6) approved by the USGS (Turnipseed and Sauer 2010) and used in previous works (Hubbart et al. 2017; Zeiger and Hubbart 2017, Zeiger and Hubbart 2016, Rehmel 2007). Streamflow measurements were conducted on a regular basis and during medium and high (peak) flow events.

Prior to conducting streamflow measurements at each study site, the wetted widths were determined to ensure an appropriate number of vertical transects were taken. Prior studies conducted by the USGS, have shown that the distance between each vertical should not exceed more than 10% of the total streamflow and consist of approximately 20 transects, with the sample time of 40 seconds. This ensures that an appropriate number of velocity recordings are recorded to accurately calculate streamflow for the stream channel (Turnipseed and Sauer 2010; Buchanan and Somers 1976). Therefore, in this study, sites that had a wetted width less than 200 cm, the maximum distance between each collected vertical transect was 7.5 cm. For the sites that had a wetted width between 200 and 400 cm, the maximum distance between each vertical

transect was 15 cm. Finally, for sites that had a wetted width over 400 cm, the maximum distance between vertical transects was 30 cm.

The appropriate point-method was determined at each transect and was variable based upon water depth during data collection. For transects that had a water depth less than 50 cm, the single-point method (0.6) was used. For transects that had a water depth above 50 cm, the two-point method (0.2 and 0.8) was used. For several of the transects collected, the three-point method (0.2, 0.6, and 0.8) was used when the Flowtracker 2[®] had abnormal readings in velocity between the 0.2 and 0.8 observations (Turnipseed and Sauer 2010; Rantz et al. 1982a).

During high flow events, when stage rapidly changed, streamflow measurements were recorded as quickly as possible. This reduced the chances of errors in the streamflow measurement caused by shifting in velocity patterns or any other variables that might occur during changes in stage (Turnipseed and Sauer 2010). This was accomplished by reducing the number of vertical transects collected to the maximum of 15, reducing sample time to between 20 to 30 seconds, and only using the single-point method (0.6) (Turnipseed and Sauer 2010; Rantz et al. 1982a). Previous studies by Carter and Anderson (1963) and the USGS (Turnipseed and Sauer 2010; Rantz et al. 1982a; Buchanan and Somers 1969) have shown that using this method will produce a standard error of 4.2%. This is comparable to the 2.2% standard error that is obtained when using the two-point method with approximately 25 verticals with a sampling time of 40 seconds.

Figure 6. A representation of a typical cross-section with stream channel divided into vertical transects for water depth and velocity to be measured when using the 0.6 method.

Stream Channel Morphological Features

At each study site, a series of channel morphological features were recorded, including channel width (m), depth (m), and bankfull (m) as per the methods of Harrelson et al. 1994. Using the measured channel depth and width, the cross-sectional area was calculated. In addition to measuring the morphological features, each stilling well's position and depth was recorded in relation to the stream bank, along with the distance between the stilling well and the location of the stream cross-section. Using these data, a series of stream channel profiles were created, including a cross-section view and plan view profile for each site (Figures A1-3 to A21-3, A1-4 to A21-4). The profiles included positioning of the stilling well in reference to the cross-section where streamflow was measured. The availability of both the cross-section and plan view profiles for each study site will allow practitioners to select the rating curve that best represents their stream

Before either of the channel profiles could be created, bankfull was identified. To determine bankfull, key indicators were assessed, which included vegetation shifts (e.g., aquatic

to terrestrial), bank slope, changes in bank material (e.g., from coarse gravel to sand), undercuts, or mineral deposits (stain lines) along boulders or bedrock (Hooper and Hubbard 2016; Harrelson et al. 1994). Once bankfull was determined, a tag line was stretched across the stream channel and leveled. For the cross-sectional profile, channel depth was recorded at 10 cm increments for channels widths equal to or less than 5 m. For bankfull widths greater than 5 m, channel depth was recorded at increments of 25 cm.

For the development of the plan view profile, bankfull was measured at four different locations at each monitoring site; at stilling well, at the point where streamflow was measured (cross-section), and upstream and downstream from the stilling well. The distance measured upstream and downstream, depended upon the distance between the stilling well and the location where streamflow was measured. Any meanders, bends, or other permanent manmade features (bridges, culverts, etc.) in the channel that were encompassed in the section were noted. When measuring bankfull at the stilling well, the distance between stilling well and the bank were also noted. By including these features upstream and downstream from where the streamflow measurements were collected, a better understanding of the channel was gained. A list of channel characteristics recorded at each site can be found in Tables 10 and 11. For visual aids of channel characteristics, photos were taken at each gauging site (Figure A1-5 to A21-5).

Rating Curve Development

To find the best fit function for the 21 gauging sites in the WRW, observed streamflow measurements and simultaneous stage were plotted and fitted with both the power-law regression and 2nd degree polynomial equations. These two functions have commonly been used to generate rating curve equations by the USGS, Phillips (2009), and Sivapragasam and Muttill (2005). Upon reviewing the coefficient of determination (R^2) for both best fit functions used, the 2nd degree polynomial function was found to produce a better R^2 value. The 2nd degree polynomial functions were then used to develop the rating curve at each gauging site.

Observed streamflow estimates were then modeled using the generated 2nd degree polynomial equations to create an “ideal curve” for each site. The “ideal curves” were used while collecting additional stream cross section data to target specific stage depths needed to fill missing points along the observed rating curves. An example of the observed rating curve next to the corresponding “ideal curve” can be found in Figure 7. For final rating curve development, outliers were removed from the data set and a final rating equation and R^2 value was generated. Tables containing the final rating equations and R^2 values can be found in Figures A1-3 to A21-3.

Figure 7. The generated rating curve (left) next to the “ideal curve” (right). This “ideal curve” was used during the initial development of the rating curves for the WRW.

Empirical Streamflow Models

Streamflow was estimated at each site using three empirical models, including: Manning's Discharge Equation (Equation 4), Chezy Discharge Equation (Equation 5 and 6), and Dingman & Sharma Discharge Equation (Equation 7). Originally developed in the mid-1700s, by Antoine Chezy, the Chezy equation was based on the principles of the force-balance but was later modified for open-channel streamflow (Dingman and Sharma 1997). Derived from the Chezy equation, Manning's equation is one of the most used empirical streamflow models due to the ability to estimate streamflow in rough, turbulent open-channel streamflow (Dingman and Sharma 1997; Rantz et al. 1982b). However, determining the roughness coefficients for both the Chezy equation and the Manning's equation can be difficult in streams with steep slopes and rocky channels, so Dingman and Sharma (1997) developed an equation that does not rely on a constant, such as Manning's n , but instead relies on hydraulic radius and slope to estimate streamflow (Dingman and Sharma 1997). Because of the frequency of use and results from previous studies completed in similar terrains and land-uses, these three empirical models were selected for this work (Dingman 2008; Sivapragasam and Muttill 2005; Dingman and Sharma 1997; Rantz et al. 1982b).

Additional characteristics and analyses of the stream channel needed to force the above models were collected at each site. This included channel slope (m), roughness, cross-sectional area (m²), wetted perimeter (m), and hydraulic radius (m). Channel roughness values were assigned during a field visit to each site using the method developed by Cowan (1956). Where the value n is determined by

$$n = m(n_0 + n_1 + n_2 + n_3 + n_4) \quad (15)$$

where m is the meander correction factor, n_0 is the base value of n for a smooth, uniform channel, n_1 is the correction for surface irregularities, n_2 is the correction for channel shape and size, n_3 is a correction for obstructions in the channel (non-living), n_4 is a correction for vegetation and flow conditions within the channel. A list of values used to assign the Manning's n roughness coefficient can be found in Table 5. The Manning's n value determined for each of the study sites can be found in Tables A1-2 to A21-2.

The channel slope was estimated using two different methods at each of the monitoring sites including an infield survey and Digital Elevation Models (DEM). The infield method included utilization of a tag line, inclinometer, stadia rod, and two field workers. A 25-m tag line was stretched out so that the measured section would include both the location of the stilling well and where the cross-sections were collected. One field worker took a gauging rod with a yellow piece of tape marking eye height for the other field worker, upstream to the end of the tag line and placed the bottom of the stadia rod at the water surface. The other field worker went downstream to the other end of the tag line and stood on a rock at the water surface. Then using the inclinometer, the lower field worker targeted the yellow piece of tape and recorded the slope (Fitz et al. 2006, Kaufmann and Robinson 1998, Gordon et al. 1994). To measure channel slope using Digital Elevation Models (DEM), the 10-m DEM and National Hydrography Dataset (NHD) streamline data sets were downloaded to ArcGIS for the study watershed. A 50-m section of the stream channel was marked using the pour-point feature. The 50-m section of stream channel was established so that it would include both the stilling well and location where the cross-sections were collected. The elevation was recorded at the bottom and the top of the 50-m stream section. Slope was then calculated using the rise over run method (Nagel et al. 2010; Nagel et al. 2006). A list of observed and calculated slopes can be found in Tables A1-2 to A21-

2. The cross-sectional area and wetted perimeter were calculated for each streamflow measurement using the Sontek Flowtracker 2[®]. The Flowtracker 2[®] handheld automatically calculated the cross-section area, based the total width of the channel (distance traveled along the tag line) and mean depth of all the vertical transects (Sontek/YSI 2003). Wetted perimeter was calculated by hand using the same measurements (Fritz et al. 2006; Harrelson et al. 1994). Hydraulic radius was then calculated for each of the streamflow measurements using the calculated cross-sectional area and wetted perimeter. Cross-sectional area and wetted perimeter were also calculated for bankfull using the measurements collected at each site (Fritz et al. 2006; Harrelson et al. 1994). Utilizing the cross-sectional area and wetted perimeter, the hydraulic radius was calculated for collected streamflow measurement and bankfull at each site.

Table 5. Reference table for estimating Manning's n (recreated from Arcement and Schneider 1989).

<i>n</i> Base Values (n_0)			
Bed Material		Size of Bed Material (mm)	n Values
Coarse Sand		1-2	0.026-0.035
Gravel		2-64	0.028- 0.035
Cobble		64-256	0.03- 0.05
Boulder		>256	0.04- 0.07
<i>Adjustments for n_0</i>			
Channel Conditions		n value adjustments	Example
Surface Irregularities (n_1)	Minor	0.001-0.005	Slightly eroded or scoured side slopes.
	Moderate	0.006-0.01	Moderate to considerable bed roughness and moderately eroded side slopes.
	Severe	0.011-0.02	Badly eroded banks and side slopes, irregular surfaces of channel in rock.
Variations in Channel (n_2)	Alternating Occasional	0.001-0.005	Wide and narrow channel widths occasionally altering or main flow occasionally change from side to side.
	Alternation Frequently	0.01-0.015	Wide and narrow channel widths frequently altering or main flow frequently change from side to side.
Obstructions (n_3)	Negligible	0.000-0.004	Scattered obstructions, less than 5% of channel obstructed.
	Minor	0.005-0.015	Obstructions occupy less than 15% of channel.
	Appreciable	0.02-0.03	Obstructions occupy between 15 to 50% of the channel.
	Severe	0.04-0.05	Obstructions occupy more than 50% of the channel, areas of turbulence caused due to obstructions.
Vegetation and Flow Conditions (n_4)	Small	0.002-0.01	Little to no vegetation, flow about two times the height of vegetation, minor weeds and vegetation on stream side.
	Medium	0.01-0.025	Light vegetation, flow equal to one to two times the height of vegetation, little to no vegetation in streambed and moderate weeds along stream side.
	Large	0.025-0.05	Moderate vegetation, flow equal to half the height of vegetation, no significant vegetation in streambed and woody plants with some weeds along stream side.
	Very Large	0.05-0.1	Densely vegetation, flow less than half the height of vegetation, with vegetation in the streambed and woody plants with intergrown weeds along stream side.
Degree of Meandering (m)	-	1.00	-

Data analysis

Descriptive statistics were generated for all collected streamflow characteristics, observed streamflow, and modeled streamflow. Coefficient of determination (R^2) was generated for all observed rating curves and modeled rating curves (Manning's equation, Chezy equations, Dingman and Sharma equation). Using the empirical streamflow models, streamflow was estimated using both observed and calculated slopes, then estimated streamflow was compared. A comparison of observed and modeled streamflow was conducted for each using an Analysis of variance (ANOVA) Tukey multiple comparison test, with a significance threshold of $\alpha=0.05$. The Tukey MCT compares the means of all variables to the mean of every other variable and has been shown to work well when considering confidence intervals (Tukey 1949). The Tukey MCT can be applied to samples sizes that are both equal and unequal. The ability of the Tukey MCT to yield the smallest pairwise error rates have made it a standard procedure for multiple comparison tests (Helsel and Hirsch 1992). All statistical analyses were conducted using Origin Pro 2018 (OriginLab Corporation, Massachusetts, U.S.A.).

RESULTS

Stream Channel Characteristics

Stream channel characteristics for each of the 21 stream gauging sites within the West Run Watershed (WRW) encompass observed measurements and descriptive statistics (e.g., minimum, maximum, and average) (Tables 6-8).

During the 2018 to 2021 study period, observed slope ranged from 0.0075 m at Site 13 to 0.061 m at Site 2, with the average observed slope of 0.025 m. Calculated slopes ranged from 0.008 m at Site 13 to 0.085 m at Site 16, with the average calculated slope of 0.04 m.

Channel roughness (Manning's n) was estimated from 0.064 at Site 13 to 0.2 at Site 5, with the average n value of 0.13. Additional channel characteristics were collected to aid in development of the cross-sectional and plan view profiles for each site. Bankfull width at the cross-section ranged from 2.63 m at Site 11 to 15.48 m at Site 19, with an average bankfull width of 6.78 m. Channel depth from bankfull at cross-section ranged from 0.29 m at Site 11 to 1.05 m at Site 18, with an average depth of 0.61 m. The wetted perimeter at cross-section ranged from 3.17 m at Site 17 to 17.48 m at Site 19, with an average wetted perimeter of 7.99 m. The cross-sectional area ranged from 0.83 m² at Site 17 to 15.51 m² at Site 19, with an average cross-sectional area of 4.77 m². Bankfull width at the stilling wells ranged from 3.07 m at Site 14 to 15.48 m at Site 19, with an average bankfull width of 7.01 m. Distance from stilling well to the stream bank at bankfull ranged from 0.57 m at Site 8 to 6.4 m at Site 5, with the average distance of 2.32 m. Distance from stilling well to location where streamflow measurements were collected ranged from 0 m at sites 1, 5, 6, 8, 9, 13, 19, and 21 to 24.41 m at Site 20, with the average distance of 5.11 m. Bankfull width at the stilling well ranged from 3.07 m at Site 14 to 15.48 m at Site 19, with the average width of 7.01 m. Bankfull widths 25.5 m upstream from the stilling well ranged from 0.86 m at Sites 16 and 17 to 25.43 m at Site 19, with an average bankfull width of 5.92. Bankfull widths 25.5 m downstream from the stilling well ranged from 0.82 m at Site 7 to 15.61 m at Site 19.

Table 6. Field observed slope, calculated slope using DEMs in ArcGIS, and assigned roughness coefficients (Manning's n) for the 21 gauging sites in the West Run Watershed, Morgantown, West Virginia, U.S.A.

Site	Observed Slope (m)	Calculated Slope (m)	Manning's n
1	0.025	0.07	0.165
2	0.061	0.11	0.14
3	0.03	0.04	0.13
4	0.01	0.022	0.127
5	0.05	0.078	0.2
6	0.02	0.016	0.072
7	0.02	0.044	0.105
8	0.01	0.03	0.14
9	0.05	0.032	0.17
10	0.01	0.005	0.085
11	0.035	0.04	0.185
12	0.02	0.059	0.095
13	0.0075	0.008	0.064
14	0.04	0.027	0.09
15	0.01	0.041	0.135
16	0.04	0.085	0.135
17	0.02	0.06	0.16
18	0.01	0.017	0.088
19	0.015	0.011	0.135
20	0.03	0.011	0.11
21	0.01	0.029	0.115

Table 7. Measurements at each stream gauging site including bankfull channel width, wetted perimeter, average depth, and cross-sectional area in West Run Watershed, Morgantown, West Virginia, U.S.A.

Site	Bankfull Width at Cross-section (m)	Bankfull Average Depth (m)	Bankfull Wetted Perimeter (m)	Bankfull Cross-Sectional Area (m ²)
1	7.24	0.66	8.56	4.79
2	5.87	0.56	6.99	3.28
3	8.00	0.87	9.73	6.93
4	6.40	0.41	7.22	2.61
5	10.47	0.78	12.22	8.29
6	5.87	0.63	7.13	3.69
7	6.78	0.67	8.12	4.53
8	4.37	0.37	5.11	1.62
9	7.16	0.78	8.72	5.60
10	8.84	0.79	10.41	6.96
11	2.63	0.32	3.28	1.03
12	2.63	0.34	3.30	0.88
13	4.42	0.61	5.65	2.72
14	2.86	0.29	3.44	0.83
15	5.19	0.50	6.19	2.60
16	3.56	0.44	4.44	1.57
17	2.41	0.35	3.12	0.85
18	8.93	1.05	11.02	9.35
19	15.48	1.00	17.48	15.51
20	10.21	0.55	11.31	5.63
21	12.78	0.86	14.51	11.03

Table 8. Measurements at each site of bankfull at, above, and below the stilling well. The distance the stilling well is from the bank and the distance between the stilling well and where streamflow was measured for the gauging sites located in West Run Watershed, Morgantown, West Virginia, U.S.A.

Site	Stilling Well Distanced from Bank (m)	Distance from Stilling Well to Cross-Section Location(m)	Bankfull Width at Stilling Well(m)	Bankfull At Cross-Section(m)	Bankfull Width Upstream from Stilling Well(m)	Bankfull Width Down Stream from Stilling Well(m)
1	2.48	0	7.24	7.24	6.81	4.66
2	2.83	0.93	5.37	5.87	2.97	4.21
3	3.35	2.87	8.18	8.0	2.71	7.62
4	2.51	1.48	4.27	6.4	3.67	4.20
5	6.40	0	10.67	10.67	7.7	6.51
6	1.15	0	5.87	5.87	6.14	6.24
7	3.27	1.12	6.22	6.78	1.55	0.82
8	0.57	0	4.37	4.37	6.50	3.9
9	2.89	0	7.16	7.16	3.72	5.01
10	2.09	14.41	8.75	8.84	7.27	6.38
11	0.95	14.67	3.11	2.63	2.26	1.97
12	0.73	8.92	5.32	2.63	4.81	2.64
13	1.4	0	4.42	4.42	3.84	4.87
14	1.07	3.23	3.07	2.86	4.01	3.83
15	1.13	6.34	6.81	5.19	4.36	6.85
16	1.61	4.65	4.29	3.56	0.86	3.76
17	1.53	4.34	3.71	2.41	0.86	3.11
18	5.63	19.85	10.42	8.93	6.31	11.81
19	2.43	0	15.48	15.48	25.43	15.61
20	3.2	24.41	9.71	10.21	8.83	8.64
21	1.53	0	12.78	12.78	13.71	12.12

Observed and Modeled Rating Curves

Observed and modeled rating curves were generated using a sample size (n) of observed streamflow estimates ranging from 21 to 53 (Table 9). The R^2 value for the observed rating curves ranged from 0.98 to 1 at Site 16. The R^2 value for Manning's curve (observed slope) ranged from 0.68 to 0.97. The R^2 value for Manning's curve (calculated slope) ranged from 0.68 to 0.97. The R^2 value for the Chezy curve (observed slope) ranged from 0.68 to 0.97. The R^2 value for the Chezy curve (calculated slope) ranged from 0.68 to 0.97. The R^2 value for Dingman and Sharma's curve (observed slope) ranged from 0.69 to 0.97. The R^2 value for Dingman and Sharma's curve (calculated slope) ranged from 0.69 to 0.97. The sites specific R^2 values can be found in Table 9 and the 2nd degree polynomial equations for each observed and modeled rating curve can be found in Tables 10-16, along with Figure A1-1 to A21-1, Tables A1-3 to A21-3.

Table 9. Number of observations (n) used to generate the observed and modeled rating curves, and associated R^2 values for each of the study sites in the West Run Watershed, Morgantown, West Virginia, U.S.A.

Site	n	Observed Rating Curve	Manning's Curve (Obs. Slope)	Manning's Curve (Calc. Slope)	Chezy Curve (Obs. Slope)	Chezy Curve (Calc Slope)	Dingman And Sharma's Curve (Obs. Slope)	Dingman And Sharma's Curve (Calc Slope)
1	47	0.99	0.92	0.92	0.92	0.92	0.92	0.92
2	43	0.99	0.95	0.95	0.95	0.95	0.94	0.94
3	30	0.99	0.87	0.87	0.87	0.87	0.87	0.87
4	33	0.99	0.95	0.95	0.95	0.95	0.95	0.95
5	26	0.98	0.93	0.93	0.93	0.93	0.93	0.93
6	36	0.99	0.97	0.97	0.97	0.97	0.96	0.96
7	23	0.99	0.90	0.90	0.90	0.90	0.89	0.89
8	30	0.98	0.85	0.85	0.85	0.85	0.88	0.88
9	28	0.98	0.95	0.95	0.95	0.95	0.94	0.94
10	41	0.99	0.97	0.97	0.97	0.97	0.97	0.97
11	21	0.98	0.87	0.87	0.87	0.87	0.89	0.89
12	46	0.99	0.70	0.70	0.70	0.70	0.69	0.69
13	53	0.98	0.88	0.88	0.88	0.88	0.88	0.88
14	34	0.99	0.91	0.91	0.91	0.91	0.91	0.91
15	51	0.99	0.68	0.68	0.68	0.68	0.73	0.73
16	22	1	0.79	0.79	0.79	0.79	0.80	0.80
17	42	0.98	0.89	0.89	0.89	0.89	0.90	0.90
18	53	0.99	0.94	0.94	0.94	0.94	0.93	0.93
19	31	0.98	0.95	0.95	0.95	0.95	0.95	0.95
20	44	0.98	0.96	0.96	0.96	0.96	0.97	0.97
21	23	0.98	0.94	0.94	0.94	0.94	0.95	0.95
Average	36	0.99	0.89	0.89	0.89	0.89	0.9	0.9

Table 10. Observed and modeled rating curves for sites 1-3 in the West Run Watershed, Morgantown, West Virginia, U.S.A.

Site	1	2	3
Observed Rating Curve	$y = 4.8531x^2 - 1.4771x + 0.1128$	$y = 5.1563x^2 - 1.8167x + 0.1632$	$y = 0.2855x^2 + 0.8084x - 0.11$
Manning's Curve (Obs. Slope)	$y = 1.4828x^2 - 0.2545x + 0.0252$	$y = 1.015x^2 + 0.6122x - 0.1125$	$y = -0.5839x^2 + 1.6111x - 0.1058$
Manning's Curve (Calc. Slope)	$y = 2.4812x^2 - 0.4259x + 0.0421$	$y = 1.363x^2 + 0.8221x - 0.1511$	$y = -0.6742x^2 + 1.8604x - 0.1222$
Chezy Curve (Obs. Slope)	$y = 1.4828x^2 - 0.2545x + 0.0252$	$y = 1.015x^2 + 0.6122x - 0.1125$	$y = -0.5839x^2 + 1.6111x - 0.1058$
Chezy Curve (Calc Slope)	$y = 2.4812x^2 - 0.4259x + 0.0421$	$y = 1.363x^2 + 0.8221x - 0.1511$	$y = -0.6742x^2 + 1.8604x - 0.1222$
Dingman And Sharma's Curve (Obs. Slope)	$y = 2.2489x^2 - 0.3577x + 0.0365$	$y = 0.9841x^2 + 0.605x - 0.1103$	$y = -0.7748x^2 + 2.0814x - 0.1385$
Dingman And Sharma's Curve (Calc Slope)	$y = 2.6236x^2 - 0.4173x + 0.0425$	$y = 1.055x^2 + 0.6486x - 0.1182$	$y = -0.811x^2 + 2.1786x - 0.145$

Table 11. Observed and modeled rating curves for sites 4-6 in the West Run Watershed, Morgantown, West Virginia, U.S.A.

Site	4	5	6
Observed Rating Curve	$y = 2.6263x^2 - 1.0531x + 0.0971$	$y = 14.772x^2 - 6.6645x + 0.7517$	$y = 8.0958x^2 - 2.7406x + 0.2133$
Manning's Curve (Obs. Slope)	$y = 0.4886x^2 + 0.8166x - 0.1505$	$y = 5.1071x^2 - 1.8233x + 0.192$	$y = 6.926x^2 - 1.5484x + 0.0768$
Manning Curve (Calc. Slope)	$y = 0.2689x^2 + 0.4495x - 0.0828$	$y = 6.3787x^2 - 2.2774x + 0.2398$	$y = 6.1948x^2 - 1.3849x + 0.0687$
Chezy Curve (Obs. Slope)	$y = 0.4886x^2 + 0.8166x - 0.1505$	$y = 5.1071x^2 - 1.8233x + 0.192$	$y = 6.926x^2 - 1.5484x + 0.0768$
Chezy's Curve (Calc Slope)	$y = 0.2689x^2 + 0.4495x - 0.0828$	$y = 6.3787x^2 - 2.2774x + 0.2398$	$y = 6.1948x^2 - 1.3849x + 0.0687$
Dingman And Sharma's Curve (Obs. Slope)	$y = 0.6055x^2 + 0.598x - 0.1082$	$y = 6.6269x^2 - 2.1068x + 0.202$	$y = 5.4636x^2 - 1.1135x + 0.0356$
Dingman And Sharma's Curve (Calc Slope)	$y = 0.7589x^2 + 0.7494x - 0.1356$	$y = 7.0238x^2 - 2.2329x + 0.2141$	$y = 5.237x^2 - 1.0673x + 0.0341$

Table 12. Observed and modeled rating curves for sites 7-9 in the West Run Watershed, Morgantown, West Virginia, U.S.A.

Site	7	8	9
Observed Rating Curve	$y = 4.3642x^2 - 0.5242x + 0.0131$	$y = 5.2729x^2 - 1.3358x + 0.062$	$y = 5.15x^2 - 0.6067x - 0.0302$
Manning's Curve (Obs. Slope)	$y = 5.5033x^2 - 1.2968x + 0.0942$	$y = 0.445x^2 + 0.0598x - 0.0133$	$y = 2.926x^2 + 0.9381x - 0.2067$
Manning's Curve (Calc. Slope)	$y = 8.1627x^2 - 1.9235x + 0.1397$	$y = 0.7708x^2 + 0.1036x - 0.023$	$y = 2.3408x^2 + 0.7505x - 0.1653$
Chezy Curve (Obs. Slope)	$y = 5.5033x^2 - 1.2968x + 0.0942$	$y = 0.445x^2 + 0.0598x - 0.0133$	$y = 2.926x^2 + 0.9381x - 0.2067$
Chezy Curve (Calc Slope)	$y = 8.1627x^2 - 1.9235x + 0.1397$	$y = 0.7708x^2 + 0.1036x - 0.023$	$y = 2.3408x^2 + 0.7505x - 0.1653$
Dingman And Sharma's Curve (Obs. Slope)	$y = 5.9797x^2 - 1.419x + 0.1033$	$y = 0.9378x^2 + 0.0967x - 0.0274$	$y = 2.8521x^2 + 1.738x - 0.3295$
Dingman And Sharma's Curve (Calc Slope)	$y = 6.8154x^2 - 1.6173x + 0.1178$	$y = 1.1571x^2 + 0.1194x - 0.0339$	$y = 2.6652x^2 + 1.6242x - 0.3079$

Table 13. Observed and modeled rating curves for sites 10-12 in the West Run Watershed, Morgantown, West Virginia, U.S.A.

Site	10	11	12
Observed Rating Curve	$y = 7.9224x^2 - 2.4494x + 0.1803$	$y = 3.8475x^2 - 2.4672x + 0.405$	$y = 0.8172x^2 + 0.7243x - 0.1282$
Manning's Curve (Obs. Slope)	$y = 5.985x^2 - 2.1592x + 0.2923$	$y = -0.1135x^2 + 0.6359x - 0.0757$	$y = 2.8829x^2 - 0.5451x + 0.0722$
Manning's Curve (Calc. Slope)	$y = 4.2321x^2 - 1.5268x + 0.2067$	$y = -0.1213x^2 + 0.6798x - 0.081$	$y = 4.9515x^2 - 0.9362x + 0.1239$
Chezy Curve (Obs. Slope)	$y = 5.985x^2 - 2.1592x + 0.2923$	$y = -0.1135x^2 + 0.6359x - 0.0757$	$y = 2.8829x^2 - 0.5451x + 0.0722$
Chezy Curve (Calc Slope)	$y = 4.2321x^2 - 1.5268x + 0.2067$	$y = -0.1213x^2 + 0.6798x - 0.081$	$y = 4.9515x^2 - 0.9362x + 0.1239$
Dingman And Sharma's Curve (Obs. Slope)	$y = 6.6746x^2 - 2.0624x + 0.2565$	$y = 0.253x^2 + 0.714x - 0.0638$	$y = 2.9506x^2 - 0.5409x + 0.0625$
Dingman And Sharma's Curve (Calc Slope)	$y = 5.677x^2 - 1.7542x + 0.2181$	$y = 0.2583x^2 + 0.7289x - 0.0651$	$y = 3.5044x^2 - 0.6425x + 0.0742$

Table 14. Observed and modeled rating curves for sites 13-15 in the West Run Watershed, Morgantown, West Virginia, U.S.A.

Site	13	14	15
Observed Rating Curve	$y = 4.4741x^2 - 1.2173x + 0.0741$	$y = 10.518x^2 - 4.4843x + 0.4972$	$y = 2.8601x^2 - 2.5768x + 0.5719$
Manning's Curve (Obs. Slope)	$y = 3.1634x^2 - 0.7756x + 0.1051$	$y = -1.617x^2 + 2.6303x - 0.4351$	$y = 1.8729x^2 - 2.0178x + 0.6895$
Manning's Curve (Calc. Slope)	$y = 3.2671x^2 - 0.801x + 0.1086$	$y = -1.3285x^2 + 2.161x - 0.3575$	$y = 3.7924x^2 - 4.0858x + 1.3961$
Chezy Curve (Obs. Slope)	$y = 3.1634x^2 - 0.7756x + 0.1051$	$y = -1.617x^2 + 2.6303x - 0.4351$	$y = 1.8729x^2 - 2.0178x + 0.6895$
Chezy Curve (Calc Slope)	$y = 3.2671x^2 - 0.801x + 0.1086$	$y = -1.3285x^2 + 2.161x - 0.3575$	$y = 3.7924x^2 - 4.0858x + 1.3961$
Dingman And Sharma's Curve (Obs. Slope)	$y = 3.047x^2 - 0.8263x + 0.1122$	$y = -1.1147x^2 + 1.9015x - 0.3156$	$y = 3.461x^2 - 3.5824x + 1.1681$
Dingman And Sharma's Curve (Calc Slope)	$y = 3.0924x^2 - 0.8387x + 0.1139$	$y = -1.0463x^2 + 1.7848x - 0.2962$	$y = 4.4865x^2 - 4.6438x + 1.5142$

Table 15. Observed and modeled rating curves for sites 16-18 in the West Run Watershed, Morgantown, West Virginia, U.S.A.

Site	16	17	18
Observed Rating Curve	$y = 1.5195x^2 - 0.3594x + 0.0222$	$y = 3.3489x^2 - 3.7972x + 1.0815$	$y = 1.0725x^2 + 2.9085x - 1.0574$
Manning's Curve (Obs. Slope)	$y = 0.6688x^2 - 0.1891x + 0.0343$	$y = 1.2628x^2 - 1.4439x + 0.4352$	$y = 8.2173x^2 - 4.167x + 0.6718$
Manning's Curve (Calc. Slope)	$y = 0.9692x^2 - 0.274x + 0.0497$	$y = 2.1873x^2 - 2.501x + 0.7537$	$y = 10.714x^2 - 5.4331x + 0.8759$
Chezy Curve (Obs. Slope)	$y = 0.6688x^2 - 0.1891x + 0.0343$	$y = 1.2628x^2 - 1.4439x + 0.4352$	$y = 8.2173x^2 - 4.167x + 0.6718$
Chezy Curve (Calc Slope)	$y = 0.9692x^2 - 0.274x + 0.0497$	$y = 2.1873x^2 - 2.501x + 0.7537$	$y = 10.714x^2 - 5.4331x + 0.8759$
Dingman And Sharma's Curve (Obs. Slope)	$y = 0.7683x^2 - 0.2102x + 0.0383$	$y = 2.1191x^2 - 2.4314x + 0.7331$	$y = 10.727x^2 - 5.5025x + 0.8895$
Dingman And Sharma's Curve (Calc Slope)	$y = 0.8488x^2 - 0.2322x + 0.0423$	$y = 2.5225x^2 - 2.8942x + 0.8726$	$y = 11.957x^2 - 6.1338x + 0.9915$

Table 16. Observed and modeled rating curves for sites 19-21 in the West Run Watershed, Morgantown, West Virginia, U.S.A.

Site	19	20	21
Observed Rating Curve	$y = 8.3797x^2 - 1.6169x + 0.0435$	$y = 9.1928x^2 - 6.1895x + 1.0677$	$y = 5.563x^2 + 0.4385x - 0.7907$
Manning's Curve (Obs. Slope)	$y = 6.2508x^2 - 2.5353x + 0.4757$	$y = 5.6124x^2 - 3.3138x + 0.6755$	$y = 3.5201x^2 - 0.9027x + 0.2264$
Manning's Curve (Calc. Slope)	$y = 5.3528x^2 - 2.1711x + 0.4074$	$y = 3.3985x^2 - 2.0066x + 0.409$	$y = 3.4025x^2 + 1.3579x - 0.3888$
Chezy Curve (Obs. Slope)	$y = 6.2508x^2 - 2.5353x + 0.4757$	$y = 5.6124x^2 - 3.3138x + 0.6755$	$y = 3.5201x^2 - 0.9027x + 0.2264$
Chezy Curve (Calc Slope)	$y = 5.3528x^2 - 2.1711x + 0.4074$	$y = 3.3985x^2 - 2.0066x + 0.409$	$y = 5.9945x^2 - 1.5373x + 0.3855$
Dingman And Sharma's Curve (Obs. Slope)	$y = 10.387x^2 - 3.7392x + 0.7198$	$y = 7.0352x^2 - 4.2963x + 0.8733$	$y = 5.3559x^2 - 0.4927x + 0.1239$
Dingman And Sharma's Curve (Calc Slope)	$y = 9.7462x^2 - 3.5084x + 0.6754$	$y = 5.8198x^2 - 3.5541x + 0.7224$	$y = 6.5714x^2 - 0.6046x + 0.152$

Observed and Modeled Streamflow Estimates

During the 2018 to 2021 study period, the minimum observed and modeled streamflow estimates at the 21 gauging sites ranged from 0.0001 m³/s to 0.745 m³/s (Table 17). The maximum observed and modeled streamflow estimates ranged from 0.077 m³/s to 4.771 m³/s (Table 18). The average observed and modeled streamflow estimates ranged from 0.037 m³/s to 1.115 m³/s (Table 19).

Table 17. Minimum observed and modeled streamflow (m³/s) estimates for each of the study sites in the West Run Watershed, Morgantown, West Virginia, U.S.A. Note: (Obs.) refers to streamflow estimated using observed slope and (Calc.) refers to streamflow estimated using calculated slope.

Site	Observed Streamflow	Manning's Streamflow (Obs.)	Manning's Streamflow (Calc.)	Chezy's Streamflow (Obs.)	Chezy's Streamflow (Calc.)	Dingman and Sharma's Streamflow (Obs.)	Dingman and Sharma's Streamflow (Calc.)
1	0.0001	0.007	0.011	0.007	0.011	0.011	0.013
2	0.002	0.025	0.034	0.025	0.034	0.025	0.027
3	0.010	0.018	0.021	0.018	0.021	0.022	0.023
4	0.004	0.046	0.084	0.046	0.084	0.077	0.097
5	0.001	0.015	0.019	0.015	0.019	0.025	0.025
6	0.007	0.073	0.065	0.073	0.065	0.060	0.057
7	0.004	0.01	0.015	0.01	0.015	0.01	0.012
8	0.008	0.008	0.014	0.008	0.014	0.015	0.018
9	0.012	0.037	0.03	0.037	0.03	0.05	0.047
10	0.02	0.06	0.042	0.06	0.042	0.076	0.065
11	0.014	0.111	0.119	0.111	0.119	0.184	0.188
12	0.005	0.021	0.037	0.021	0.037	0.021	0.025
13	0.021	0.026	0.027	0.026	0.027	0.025	0.025
14	0.008	0.043	0.036	0.043	0.036	0.031	0.029
15	0.001	0.008	0.015	0.008	0.015	0.013	0.016
16	0.006	0.014	0.02	0.014	0.02	0.017	0.019
17	0.001	0.006	0.011	0.006	0.011	0.009	0.011
18	0.022	0.134	0.175	0.134	0.175	0.152	0.17
19	0.074	0.199	0.17	0.199	0.17	0.367	0.344
20	0.007	0.083	0.05	0.083	0.05	0.103	0.085
21	0.091	0.334	0.568	0.334	0.568	0.607	0.745

Table 18. Maximum observed and modeled streamflow (m^3/s) estimates for each of the study sites in the West Run Watershed, Morgantown, West Virginia, U.S.A. Note: (Obs.) refers to streamflow estimated using observed slope and (Calc.) refers to streamflow estimated using calculated slope.

Site	Observed Streamflow	Manning's Streamflow (Obs.)	Manning's Streamflow (Calc.)	Chezy's Streamflow (Obs.)	Chezy's Streamflow (Calc.)	Dingman and Sharma's Streamflow (Obs.)	Dingman and Sharma's Streamflow (Calc.)
1	0.528	0.321	0.537	0.321	0.537	0.488	0.569
2	0.514	0.392	0.528	0.393	0.528	0.384	0.412
3	0.902	0.998	1.152	0.998	1.152	1.258	1.317
4	0.611	0.342	0.622	0.342	0.622	0.573	0.717
5	0.267	0.187	0.234	0.187	0.234	0.287	0.304
6	1.271	1.383	1.237	1.383	1.237	1.124	1.078
7	0.173	0.146	0.216	0.146	0.216	0.157	0.179
8	0.34	0.077	0.134	0.077	0.134	0.149	0.184
9	0.626	0.672	0.538	0.672	0.538	0.856	0.8
10	2.058	1.562	1.105	1.562	1.105	1.892	1.609
11	0.296	0.284	0.303	0.284	0.303	0.487	0.497
12	0.904	1.748	3.002	1.748	3.002	1.821	2.163
13	0.938	0.861	0.889	0.861	0.889	0.799	0.811
14	0.9	0.511	0.42	0.511	0.42	0.381	0.357
15	1.734	0.825	1.671	0.825	1.671	1.577	2.045
16	0.155	0.096	0.14	0.096	0.14	0.113	0.125
17	0.415	0.184	0.318	0.184	0.318	0.302	0.359
18	2.559	3.319	4.328	3.319	4.328	4.28	4.771
19	2.081	1.202	1.03	1.202	1.03	2.21	2.074
20	3.048	2.385	1.444	2/385	1.444	2.843	2.352
21	2.366	1.414	2.408	1.414	2.408	2.570	3.153

Table 19. Average observed and modeled streamflow (m^3/s) estimates for each of the study sites in the West Run Watershed, Morgantown, West Virginia, U.S.A. Note: (Obs.) refers to streamflow estimated using observed slope and (Calc.) refers to streamflow estimated using calculated slope.

Site	Observed Streamflow	Manning's Streamflow (Obs.)	Manning's Streamflow (Calc.)	Chezy's Streamflow (Obs.)	Chezy's Streamflow (Calc.)	Dingman and Sharma's Streamflow (Obs.)	Dingman and Sharma's Streamflow (Calc.)
1	0.104	0.071	0.119	0.071	0.119	0.113	0.132
2	0.103	0.144	0.193	0.144	0.193	0.142	0.152
3	0.207	0.336	0.388	0.336	0.388	0.429	0.449
4	0.135	0.147	0.267	0.147	0.267	0.241	0.302
5	0.130	0.123	0.154	0.123	0.154	0.191	0.203
6	0.229	0.345	0.308	0.345	0.308	0.282	0.270
7	0.051	0.040	0.059	0.040	0.059	0.043	0.049
8	0.119	0.039	0.068	0.039	0.068	0.075	0.092
9	0.142	0.193	0.155	0.193	0.155	0.255	0.238
10	0.428	0.369	0.261	0.369	0.261	0.465	0.396
11	0.097	0.183	0.196	0.183	0.196	0.305	0.311
12	0.180	0.257	0.441	0.257	0.441	0.256	0.305
13	0.365	0.344	0.356	0.344	0.356	0.311	0.316
14	0.312	0.243	0.199	0.243	0.199	0.181	0.170
15	0.191	0.226	0.458	0.226	0.458	0.407	0.527
16	0.047	0.037	0.054	0.037	0.054	0.044	0.048
17	0.188	0.089	0.154	0.089	0.154	0.146	0.174
18	0.549	0.705	0.920	0.705	0.920	0.904	1.008
19	0.683	0.474	0.406	0.474	0.406	0.887	0.832
20	0.589	0.616	0.373	0.616	0.373	0.727	0.601
21	0.467	0.514	0.876	0.514	0.876	0.941	1.155

Table 20. Standard Deviation of observed and modeled streamflow estimates for each of the study sites in the West Run Watershed, Morgantown, West Virginia, U.S.A. Note: (Obs.) refers to streamflow estimated using observed slope and (Calc.) refers to streamflow estimated using calculated slope.

Site	Observed Streamflow	Manning's Streamflow (Obs.)	Manning's Streamflow (Calc.)	Chezy's Streamflow (Obs.)	Chezy's Streamflow (Calc.)	Dingman and Sharma's Streamflow (Obs.)	Dingman and Sharma's Streamflow (Calc.)
1	0.142	0.067	0.113	0.067	0.113	0.105	0.123
2	0.14	0.124	0.167	0.124	0.167	0.122	0.13
3	0.254	0.265	0.306	0.265	0.306	0.338	0.354
4	0.144	0.08	0.145	0.08	0.145	0.131	0.164
5	0.1	0.061	0.077	0.061	0.077	0.94	0.099
6	0.318	0.347	0.31	0.347	0.31	0.285	0.273
7	0.05	0.034	0.05	0.034	0.05	0.037	0.042
8	0.124	0.024	0.042	0.024	0.042	0.048	0.059
9	0.179	0.203	0.163	0.203	0.163	0.263	0.246
10	0.535	0.372	0.263	0.372	0.263	0.457	0.389
11	0.108	0.051	0.055	0.051	0.055	0.091	0.093
12	0.266	0.423	0.727	0.423	0.727	0.439	0.521
13	0.336	0.263	0.271	0.263	0.271	0.243	0.247
14	0.369	0.179	0.147	0.179	0.147	0.134	0.126
15	0.377	0.228	0.462	0.228	0.462	0.437	0.566
16	0.056	0.024	0.034	0.024	0.034	0.028	0.031
17	0.154	0.059	0.103	0.059	0.103	0.098	0.117
18	0.651	0.869	1.133	0.869	1.133	1.127	1.257
19	0.663	0.33	0.283	0.33	0.283	0.609	0.571
20	0.82	0.591	0.358	0.591	0.358	0.713	0.59
21	0.524	0.237	0.403	0.237	0.403	0.435	0.534

Estimated streamflow using observed and modeled streamflow in sites 1, 2, 6, 7, 9, 10, 12, 13, 14, 16, 18, 19, and 20 had no differences. Differences in observed and/or modeled streamflow were found in sites 3, 4, 5, 8, 11, 15, 17, and 21. Manning and Chezy models were significantly different from observed in sites 4, 8, 11, 15, 17, and 21. Dingman and Sharma model was significantly different from observed in sites 3, 4, 5, 11, 15, and 21 (Table 21-22).

Table 21. Site by site comparison of the developed observed and modeled rating curves used to estimate streamflow for sites 3-11 in the West Run Watershed, Morgantown, West Virginia, U.S.A. Obs. slope represents observed slope collected in the field. Calc. slope represents calculated slope using ArcGIS. Only significant ($\alpha=0.05$) results from the analysis are shown.

Site	Site Comparison			<i>p</i> -Value ($\alpha=0.05$)
3	Observed Curve	vs	Dingman and Sharma's Curve (calc. slope)	0.04
4	Observed Curve	vs	Manning's Curve (calc. slope)	<0.05
		vs	Chezy's Curve (calc slope)	<0.05
		vs	Dingman And Sharma's Curve (obs. slope)	0.03
		vs	Dingman And Sharma's Curve (calc. slope)	<0.05
	Rating Equation Curve	vs	Manning's Curve (calc. slope)	<0.05
		vs	Chezy's Curve (calc slope)	<0.05
		vs	Dingman And Sharma's Curve (obs. slope)	0.03
		vs	Dingman And Sharma's Curve (calc. slope)	<0.05
	Manning's Curve (obs. slope)	vs	Manning's Curve (calc. slope)	<0.05
		vs	Chezy's Curve (calc slope)	<0.05
	Manning's Curve (calc. slope)	vs	Dingman And Sharma's Curve (calc. slope)	<0.05
		vs	Chezy's Curve (obs. slope)	<0.05
		vs	Chezy's Curve (calc slope)	<0.05
		vs	Dingman And Sharma's Curve (calc. slope)	<0.05
5	Observed Curve	vs	Dingman And Sharma's Curve (calc. slope)	0.05
	Rating Equation Curve	vs	Dingman And Sharma's Curve (calc. slope)	0.05
	Manning's Curve (obs. slope)	vs	Dingman And Sharma's Curve (calc. slope)	0.02
	Chezy's Curve (obs. slope)	vs	Dingman And Sharma's Curve (calc. slope)	0.02
8	Observed Curve	vs	Manning's Curve (obs. slope)	<0.05
		vs	Chezy's Curve (obs. slope)	<0.05
	Rating Equation Curve	vs	Manning's Curve (obs. slope)	<0.05
		vs	Chezy's Curve (obs. slope)	<0.05
11	Observed Curve	vs	Manning's Curve (obs. slope)	<0.05
		vs	Manning's Curve (calc. slope)	<0.05
		vs	Chezy's Curve (obs. slope)	<0.05
		vs	Chezy's Curve (calc. slope)	<0.05
		vs	Dingman and Sharma's Curve (obs. slope)	<0.05
		vs	Dingman and Sharma's Curve (calc. slope)	<0.05
	Rating Equation Curve	vs	Manning's Curve (obs. slope)	<0.05
		vs	Manning's Curve (calc. slope)	<0.05
		vs	Chezy's Curve (obs. slope)	<0.05
		vs	Chezy's Curve (calc. slope)	<0.05
		vs	Dingman and Sharma's Curve (obs. slope)	<0.05
		vs	Dingman and Sharma's Curve (calc. slope)	<0.05
	Manning's Curve (obs. slope)	vs	Dingman and Sharma's Curve (obs. slope)	<0.05
		vs	Dingman and Sharma's Curve (calc. slope)	<0.05
	Manning's Curve (calc. slope)	vs	Dingman and Sharma's Curve (obs. slope)	<0.05
		vs	Dingman and Sharma's Curve (calc. slope)	<0.05
	Chezy's Curve (obs. slope)	vs	Dingman and Sharma's Curve (obs. slope)	<0.05
		vs	Dingman and Sharma's Curve (calc. slope)	<0.05
	Chezy's Curve (calc. slope)	vs	Dingman and Sharma's Curve (obs. slope)	<0.05
		vs	Dingman and Sharma's Curve (calc. slope)	<0.05

Table 22. Site by site comparison of the developed observed and modeled rating curves used to estimate streamflow for sites 5-21 in the West Run Watershed, Morgantown, West Virginia, U.S.A. Obs. slope represents observed slope collected in the field. Calc. slope represents calculated slope using ArcGIS. Only significant ($\alpha=0.05$) results from the analysis are shown.

Site	Site Comparison		<i>p</i> -Value ($\alpha=0.05$)
15	Observed Curve	vs Manning's Curve (calc. slope)	0.02
		vs Chezy's Curve (calc slope)	0.02
		vs Dingman And Sharma's Curve (calc. slope)	<0.05
	Rating Equation Curve	vs Manning's Curve (calc. slope)	0.02
		vs Chezy's Curve (calc slope)	0.02
		vs Dingman And Sharma's Curve (calc. slope)	<0.05
	Manning's Curve (obs. slope)	vs Dingman And Sharma's Curve (calc. slope)	0.05
	Chezy's Curve (obs. slope)	vs Dingman And Sharma's Curve (calc. slope)	0.05
17	Observed Curve	vs Manning's Curve (obs. slope)	<0.05
		vs Chezy's Curve (obs. slope)	<0.05
	Rating Equation Curve	vs Manning's Curve (obs. slope)	<0.05
		vs Chezy's Curve (obs. slope)	<0.05
	Manning's Curve (obs. slope)	vs Dingman And Sharma's Curve (calc. slope)	<0.05
	Chezy's Curve (obs. slope)	vs Dingman And Sharma's Curve (calc. slope)	<0.05
21	Observed Curve	vs Manning's Curve (calc. slope)	0.03
		vs Chezy's Curve (calc slope)	0.03
		vs Dingman and Sharma's Curve (obs.slope)	<0.05
	Rating Equation Curve	vs Dingman And Sharma's Curve (calc. slope)	<0.05
		vs Manning's Curve (calc. slope)	0.03
		vs Chezy's Curve (calc slope)	
		vs Dingman and Sharma's Curve (obs.slope)	<0.05
	Manning's Curve (obs. slope)	vs Dingman And Sharma's Curve (calc. slope)	<0.05
		vs Dingman and Sharma's Curve (obs.slope)	0.02
		vs Dingman And Sharma's Curve (calc. slope)	<0.05
		vs Dingman and Sharma's Curve (obs.slope)	0.02
	Chezy's Curve (obs. slope)	vs Dingman And Sharma's Curve (calc. slope)	<0.05

DISCUSSION

Stream Channel Characteristics

Slope was an important component used to estimate streamflow in the models selected. Slope varied significantly between field observed and computer (ArcGIS) calculated. Percent difference ranged from 6.7% at Site 13 to 310% at Site 15. The main objective of this project was to develop a series of rating curve equations in a mixed-land-use watershed using observed and computer-generated data. Our results show the need of caution when using computer generated slope, as it may vary significantly from field observed measurements, which may create an unreliable streamflow estimation.

Another key component for estimating streamflow via the Manning's and Chezy models is the roughness coefficient (n). Determining the appropriate n value was difficult at several of the study sites, particularly at sites that have had major influences from anthropogenic activities or with slopes greater than 0.04 m. The challenge of assigning an n value at sites with steep slopes followed closely with previous studies by Dingman and Sharma (2007), Jarrett (1984), and Riggs (1976), which were also conducted in mountainous streams.

Observed and Modeled Rating Curve

During development of the observed rating curve, the coefficient of determination (R^2) was used to validate rating curve accuracy. The minimum R^2 value (i.e., threshold) chosen for this study was $R^2 \geq 0.95$. For the observed rating curves, the minimum R^2 values were 0.98 at Sites 8, 9, 11, 13, 17, 19, 20, and 21, the maximum R^2 value was 1 at Site 16, with an average R^2 value of 0.99. However, many of the modeled ratings curves used in this study did not generate R^2 values greater than 0.95. For rating curves generated at Sites 2, 4, 6, 10, 19, 20, and 21, at least one empirical model did produce a $R^2 \geq 0.95$. The lowest R^2 values generated for the Manning's and Chezy equations were at Site 15 ($R^2 = 0.68$) and for the Dingman and Sharma

equation was at Site 12 ($R^2 = 0.69$). The highest R^2 value generated from the empirical models was 0.97. This R^2 value was produced at Site 10 for all three of the models used. Variations in the R^2 values means that several of the models would not be reliable for estimating future streamflow.

Observed and Modeled Streamflow Estimates

In this study, observed streamflow estimates were compared against modeled streamflow estimates using Manning, Chezy, and Dingman and Sharma equations. 8 of 21 study sites showed significant differences between observed and/or modeled streamflow estimates. In general, the Dingman and Sharma model performed the worst in comparison to the Manning and Chezy models (Table 23). The Dingman and Sharma model showed at least one model estimated streamflow (observed slope or calculated slope), with significant differences to observed estimated streamflow. For example, at Sites 4 and 21, the Dingman and Sharma model showed significant differences with observed streamflow when using both the observed and calculated slopes. A notable difference between the Dingman and Sharma model and the Manning/Chezy models is the use of a roughness coefficient (n). The Dingman and Sharma model utilizes cross-sectional area, hydraulic radius, and water-surface slope to avoid uncertainty in selecting a roughness coefficient (Dingman and Sharma 2007; Riggs 1976). In this study, the use of a roughness coefficient (n) was more reliable at estimating streamflow.

Table 23. P-values for statistically significant study sites in WRW. Note: (Obs.) refers to streamflow estimated using observed slope and (Calc.) refers to streamflow estimated using calculated slope.

Site	Manning		Chezy		Dingman and Sharma	
	Obs.	Calc.	Obs.	Calc.	Obs.	Calc.
3						<0.05
4		<0.05		<0.05	<0.05	<0.05
5						0.05
8	<0.05		<0.05			
11	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
15		<0.05		<0.05		<0.05
17	<0.05		<0.05			
21		<0.05		<0.05	<0.05	<0.05

Significant differences were found between modeled streamflow and observed streamflow for all the models used at Site 11. This issue could be the result of several factors, including the incorrectly assigned roughness coefficient (n), incorrectly measured slope (observed and calculated), or anthropogenic stream channel alterations. Assigning n was difficult at Site 11 due to a rapid change in vegetation in the stream channel during different flow events and variations in channel width associated with physical channel alterations (e.g., a bridge). Channel confinement caused by the bridge could easily lead to backwatering at the location where streamflow was measurement.

Even though only 8 sites showed significant differences between observed and modeled streamflow, this was based on mean streamflow. Relative to observed results, empirical models

poorly estimated low flows at the majority of the 21 study sites. Percent differences between observed and modeled low flows ranged from 12.5% at Site 8 to 12,900% at Site 1. The models were more accurate when estimating streamflow during high flow events, with the percent differences ranging from 0% at Site 2 to 232% at Site 12. The inaccuracy of model estimated streamflow, especially from the Manning's and Chezy equations, could be a result of incorrectly assigned n values. Since channel roughness can change during different flow events (e.g., low, medium, and high), the n value for a site can also change, resulting in a need to assign more than one n value at each site (Dingman and Sharma 2007). Studies by Harmel et al. (2006), and Slade (2004) have shown that modeled streamflow using the Manning's equation can result in uncertainties ranging from $\pm 15\%$, in stable channels with a poor n value, to $\pm 35\%$, in unstable channels with a poor n value. Additionally, studies by Hodgkin et al. (2020), Farmer et al. (2015), have shown that, in general, models are calibrated for estimating streamflow during medium and high flow events, but inaccurately estimate streamflow during low flow events. These results emphasize the need for model validation to improve streamflow estimates, especially for low flow events.

Implications of Study

This study measured cross-sectional streamflow at 21 gauging sites throughout West Run Watershed. A total of 757 cross-sections were performed, with an average of 36 at each site. Manually measuring streamflow at multiple sites throughout a watershed can be a difficult task, with limited instruments and users available during rain events. While using models to estimate streamflow is a much easier task, there can be estimation errors if slope is incorrectly calculated or if the roughness coefficient is incorrectly selected. If directly relying on models to estimate streamflow, the user should practice caution as the estimation could vary from observed flow.

This study showed that GIS calculated slope using 10 m DEM can vary from field calculated slope, emphasizing the need for the use of a higher resolution DEM or field surveys to measure slope.

Study Challenges

Several challenges were encountered during the completion of this study. For example, as mentioned in previous studies by the USGS and Dingman and Sharma (2007), assigning the correct n value can be difficult, especially for inexperienced researchers. Inexperience researchers would benefit from either hands-on training from an experienced researcher or the development of an in-depth key that thoroughly explains the assignment selection of the roughness coefficient (n). Additional challenges included a period of drought during the summer of 2020, that resulted in no observable streamflow at several of the gauging sites. Moreover, towards the middle of the 2021 study year, locally intense rainfall events occurred that produced flashy, high flow. These flashy storm events posed a challenge for targeting sites for streamflow collection. Due to distance between certain study sites, the limited number of field personnel to collect streamflow, and the rapid recession of stage and streamflow, certain sites did not have streamflow measurements collected as frequently. This infrequent streamflow collection resulted in sample size (n) variability from 21-53 across the 21 study sites. Future work would benefit from a larger field crew to be able to collect streamflow estimates simultaneously, especially during droughts with flashy rain events.

CONCLUSION

Modeled and observed streamflow varied in this study. The models selected poorly estimated streamflow, especially during low flow events. Accurate streamflow estimation is important for improved management of water resources (e.g., water allocation, pollutant loading, etc.) and aquatic habitat (Erwin and Hamilton 2002). Due to labor constraints caused by the need to continuously collect streamflow measurements to generate site specific rating curves, streamflow is commonly estimated using various streamflow models (USGS 2019). However, previous studies by Hodgkins et al. (2020), Farmer et al. (2014), Dingman and Sharma (2007), Jarrett (1984), and Riggs (1976) have shown that several streamflow models greatly overestimate/underestimate streamflow. For example, estimated streamflow using the Manning or Chezy equations can be difficult due to the reliance of the models on the correctly assigned roughness coefficient (n) and slope of a stream channel (Dingman and Sharma 2007). Assigning n can be especially difficult in stream channels with steep gradients, like ones found in mountainous regions similar to the Appalachians.

To advance understanding of observed streamflow and estimating streamflow using models in mountainous regions, a 21-site, nested-scale, experimental watershed study design was implemented in a mixed-land-use Appalachian watershed of the eastern United States (Petersen and Hubbart 2020b; Hubbart et al. 2019; Hubbart et al. 2007; Loftis et al. 2001). Using the high spatial resolution of the experimental watershed design, understanding of the stage versus streamflow relationship, on a site-by-site level, can be improved by developing transferable rating curves. Additionally, observed streamflow measurements were compared with streamflow estimated using three different empirical streamflow models (Manning's, Chezy, and Dingman and Sharma) to validate model accuracy.

Results from this study showed that there were significant differences ($\alpha=0.05$) between observed and modeled mean streamflow estimates at 8 of the 21 sites in the West Run watershed (WRW). Out of the sites that showed significant differences between observed and modeled streamflow, 8 sites showed significant differences between observed streamflow and modeled streamflow using the Dingman and Sharma's equation and 6 sites showed significant differences between observed streamflow and modeled streamflow using the Manning's or Chezy equations. The significant differences between observed streamflow and modeled streamflow using the Manning's or Chezy equations could be due to incorrectly assigned roughness coefficients (n) or variations in observed and calculated slope. Differences between observed streamflow and modeled streamflow using the Dingman and Sharma's equation, may well be linked to the variations between observed slope and calculated slope.

Even though only 8 of the 21 sites showed significant differences between mean observed and modeled streamflow, the models inaccurately estimated streamflow during low flow events at most of the study sites within the WRW. Percent differences between observed streamflow and modeled streamflow ranged from 12.8% at Site 8 to 12,900% at Site 1. Most of the differences between observed and modeled streamflow estimates during low flow events were overestimations. This inability to properly estimate low flows using these models poses a potential problem for land and water resource managers. The findings in this study, though preliminary, emphasize the need to validate estimated streamflow with observed streamflow when using models. Additionally, conclusions made by previous researchers were both reinforced and expanded on through the investigation and interpretation of these data.

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APPENDIX 1: Site 1

Table A1-1. Streamflow measurements and stage collected at Site 1, West Run Watershed, Morgantown, WV, U.S.A. (Figure 2).

Date	Mean Depth of Cross-Section (m)	Stage(PT in cm)	Barometric Pressure (in cm)	Pressure Corrected Stage (cm)	Stilling Well Offset (cm)	P-Corrected Stage + Offset (cm)	P-Corrected Stage + Offset (m)	SonTec Discharge (m3/s)	Rating Equation Discharge (m3/s)
12/2/2017	0.0605	97.54	89.21	8.33	3.2	11.53	0.1153	0.0030	0.007007918
1/2/2018	0.0543	111.7	103.13	8.57	3.2	11.77	0.1177	0.0018	0.006176732
1/9/2018	0.0586	102.44	94.2	8.24	3.2	11.44	0.1144	0.0029	0.007334027
1/23/2018	0.1031	89.83	74.14	15.69	3.2	18.89	0.1889	0.0122	0.006949996
3/8/2018	0.0586	88.86	77.9	10.96	3.2	14.16	0.1416	0.0063	0.000950013
3/29/2018	0.0721	92.36	79.92	12.44	3.2	15.64	0.1564	0.0109	0.000493045
4/4/2018	0.1096	92.98	75.59	17.39	3.2	20.59	0.2059	0.0240	0.014411362
4/20/2018	0.0713	107.56	96.88	10.68	3.2	13.88	0.1388	0.0096	0.001275627
7/16/2018	0.0604	93.16	83.78	9.38	3.2	12.58	0.1258	0.0002	0.003784233
7/23/2018	0.0622	89.63	80.44	9.19	3.2	12.39	0.1239	0.0014	0.004288267
7/23/2018	0.0750	89.62	80.5	9.12	3.2	12.32	0.1232	0.0001	0.004482797
7/25/2018	0.0753	92.67	82.94	9.73	3.2	12.93	0.1293	0.0009	0.002947474
7/25/2018	0.0759	92.58	82.99	9.59	3.2	12.79	0.1279	0.0018	0.00326791
8/30/2018	0.0826	99.12	89.03	10.09	3.2	13.29	0.1329	0.0023	0.002210852
8/30/2018	0.0808	99.2	89.2	10	3.2	13.2	0.132	0.0020	0.002383214
9/9/2018	0.2411	124.11	81.51	42.6	3.2	45.8	0.458	0.4256	0.454293868
9/11/2018	0.0805	104.55	89.4	15.15	3.2	18.35	0.1835	0.0085	0.005166946
9/18/2018	0.1199	97.2	81.83	15.37	3.2	18.57	0.1857	0.0111	0.005859208
9/25/2018	0.1890	119.74	92.1	27.64	3.2	30.84	0.3084	0.1151	0.118843419
10/4/2018	0.1006	94.54	85.3	9.24	3.2	12.44	0.1244	0.0026	0.004152223
10/4/2018	0.0930	94.33	85.13	9.2	3.2	12.4	0.124	0.0058	0.004260866
10/30/2018	0.0954	103.46	89.61	13.85	3.2	17.05	0.1705	0.0048	0.00203528
12/17/2018	0.0860	97.7	85.18	12.52	3.2	15.72	0.1572	0.0072	0.000528911
12/31/2018	0.1518	100.07	78.85	21.22	3.2	24.42	0.2442	0.0500	0.041500198
12/31/2018	0.1643	102.66	79.51	23.15	3.2	26.35	0.2635	0.0416	0.060545802
1/23/2019	0.0978	92.3	78.18	14.12	3.2	17.32	0.1732	0.0108	0.002550739
2/12/2019	0.1460	98.21	76.2	22.01	3.2	25.21	0.2521	0.0485	0.048858997
3/25/2019	0.1024	100.44	83.12	17.32	3.2	20.52	0.2052	0.0090	0.014048756
4/2/2019	0.0884	99.45	86.02	13.43	3.2	16.63	0.1663	0.0024	0.001374099
4/12/2019	0.1170	100.93	80.97	19.96	3.2	23.16	0.2316	0.0156	0.031016936
7/5/2019	0.4109	131.71	85.91	45.8	3.2	49.00	0.49	0.5284	0.55425031
10/31/2019	0.2567	103.61	70.71	32.9	3.2	36.10	0.361	0.2318	0.212027745
12/17/2019	0.1785	98	73.6	24.4	3.2	27.60	0.276	0.0669	0.074810146
11/11/2020	0.248	1022.4	996.41	26	3.2	29.20	0.292	0.102	0.095281518
11/11/2020	0.261	1024.9	996.45	28.5	3.2	31.70	0.317	0.1077	0.132242466
4/29/2021	0.237	1022.4	988.82	33.6	3.2	36.80	0.368	0.218	0.226453414
4/29/2021	0.221	1019.9	988.99	30.9	3.2	34.10	0.341	0.1502	0.173432221
4/29/2021	0.209	1016.2	989.26	26.9	3.2	30.10	0.301	0.1112	0.107888613
8/16/2021	0.251	1039	1002.48	36.5	3.2	39.70	0.397	0.2812	0.291283538
8/16/2021	0.228	1036.4	1002.56	33.8	3.2	37.00	0.37	0.251	0.23066239
8/16/2021	0.219	1034.2	1002.60	31.6	3.2	34.80	0.348	0.1842	0.186499022
8/16/2021	0.2	1034.2	1002.65	31.6	3.2	34.80	0.348	0.1606	0.186499022
9/1/2021	0.326	1028.3	988.24	40.1	3.2	43.30	0.433	0.4169	0.383118566
9/1/2021	0.287	1027.6	988.28	39.3	3.2	42.50	0.425	0.3957	0.361623688
9/1/2021	0.275	1026.6	988.34	38.3	3.2	41.50	0.415	0.3688	0.335628648
9/1/2021	0.234	1023	988.53	34.5	3.2	37.70	0.377	0.2469	0.24569955
9/1/2021	0.226	1022.7	988.36	34.3	3.2	37.50	0.375	0.2439	0.241354688

Table A1-2. Modeled streamflow at Site 1, West Run Watershed, Morgantown, WV, U.S.A.

Cross-Section Area (m ²)	A (Cross Section area of flow) m ²	P (Wetted Perimeter)	RH=A/P Hydraulic Radius (m)	Observed Slope (m)	Calculated Slope using ArcGIS (m)	Roughness Coefficient (n)	Manning Discharge (m ³ /s) (Obs Slope)	Manning Discharge (m ³ /s) (Calc Slope)	Cheyzy Coefficient (C)	Cheyzy Discharge (m ³ /s) (Obs Slope)	Cheyzy Discharge (m ³ /s) (Calc Slope)	Dingman & Sharma Discharge (m ³ /s) (Obs. Slope)	Dingman & Sharma Discharge (m ³ /s) (Calc Slope)
4.79	0.061	1.5484	0.039716	0.025	0.07	0.165	0.00685975	0.01147855	3.54005725	0.006859746	0.01147855	0.011851463	0.013826519
4.79	0.065	1.5586	0.041913	0.025	0.07	0.165	0.00755331	0.012639113	3.57197146	0.007553314	0.012639113	0.012998837	0.015165105
4.79	0.060	1.5445	0.038885	0.025	0.07	0.165	0.00660574	0.011053518	3.52760095	0.00660574	0.011053518	0.011430342	0.013335219
4.79	0.179	1.8388	0.097319	0.025	0.07	0.165	0.03628062	0.060709087	4.11038344	0.036280619	0.060709087	0.059373727	0.069268411
4.79	0.103	1.6575	0.062422	0.025	0.07	0.165	0.0156018	0.0261068	3.81715276	0.015601797	0.0261068	0.026144338	0.030500149
4.79	0.127	1.7163	0.074045	0.025	0.07	0.165	0.02147366	0.035932302	3.92734524	0.021473658	0.035932302	0.035625823	0.041562898
4.79	0.206	1.8992	0.108506	0.025	0.07	0.165	0.04492423	0.075172611	4.18560511	0.044924228	0.075172611	0.073181967	0.085377806
4.79	0.098	1.5146	0.064704	0.025	0.07	0.165	0.01513553	0.025326581	3.84005469	0.015135527	0.025326581	0.024885709	0.029032934
4.79	0.073	1.3394	0.054502	0.025	0.07	0.165	0.01005582	0.016826598	3.73179819	0.010055816	0.016826598	0.016448008	0.019189083
4.79	0.08	1.4192	0.05637	0.025	0.07	0.165	0.01127043	0.018859029	3.75281469	0.011270425	0.018859029	0.018561526	0.021654821
4.79	0.097	1.4452	0.067119	0.025	0.07	0.165	0.0153516	0.02568814	3.86358098	0.0153516	0.02568814	0.024951194	0.029109332
4.79	0.109	1.5988	0.068176	0.025	0.07	0.165	0.01743147	0.029168436	3.87365955	0.017431475	0.029168436	0.028788882	0.033586575
4.79	0.11	1.6	0.06875	0.025	0.07	0.165	0.01768997	0.02960099	3.87907497	0.017689975	0.02960099	0.029196667	0.034062317
4.79	0.12	1.6012	0.074944	0.025	0.07	0.165	0.02044048	0.034203464	3.93524703	0.02044048	0.034203464	0.033469131	0.039046792
4.79	0.118	1.6132	0.073147	0.025	0.07	0.165	0.01977716	0.033093519	3.91935879	0.01977716	0.033093519	0.032498677	0.037914611
4.79	0.625	3.0734	0.203358	0.025	0.07	0.165	0.20711268	0.346565808	4.6475729	0.207112684	0.346565808	0.345734092	0.403350984
4.79	0.129	1.7612	0.073246	0.025	0.07	0.165	0.02164029	0.036211135	3.92024216	0.021640292	0.036211135	0.036099794	0.042115856
4.79	0.177	1.9546	0.090556	0.025	0.07	0.165	0.03420342	0.057233274	4.06133317	0.034203423	0.057233274	0.05695205	0.06644316
4.79	0.417	2.5878	0.161141	0.025	0.07	0.165	0.11832931	0.198002814	4.47078323	0.118329314	0.198002814	0.195962199	0.228619473
4.79	0.115	1.3442	0.085553	0.025	0.07	0.165	0.02139636	0.035802956	4.02304645	0.021396359	0.035802956	0.03357088	0.039165496
4.79	0.106	1.3292	0.079747	0.025	0.07	0.165	0.01881925	0.031490626	3.97620388	0.018819249	0.031490626	0.029664741	0.034608397
4.79	0.138	1.639	0.084198	0.025	0.07	0.165	0.02540379	0.042508677	4.01235556	0.025403793	0.042508677	0.041311294	0.048195857
4.79	0.15	1.9246	0.077938	0.025	0.07	0.165	0.02622675	0.04388575	3.96102745	0.026226752	0.04388575	0.044169851	0.051530795
4.79	0.263	1.9234	0.136737	0.025	0.07	0.165	0.06689072	0.111929591	4.5007834	0.066890724	0.111929591	0.106864417	0.124673467
4.79	0.258	1.9288	0.133762	0.025	0.07	0.165	0.06466373	0.108203121	4.33415868	0.064663733	0.108203121	0.103569885	0.120829897
4.79	0.142	1.6438	0.086385	0.025	0.07	0.165	0.02659096	0.044495183	4.02954445	0.026590958	0.044495183	0.043159912	0.050352549
4.79	0.245	1.968	0.124492	0.025	0.07	0.165	0.05853462	0.097947154	4.28258726	0.05853462	0.097947154	0.094715005	0.110499344
4.79	0.156	1.729	0.090226	0.025	0.07	0.165	0.0300721	0.050320245	4.05886235	0.030072098	0.050320245	0.049038544	0.057210861
4.79	0.115	1.472	0.078125	0.025	0.07	0.165	0.02013928	0.03369946	3.96260753	0.020139279	0.03369946	0.032373164	0.037768181
4.79	0.17	1.6822	0.101058	0.025	0.07	0.165	0.03534401	0.059141844	4.13629277	0.035344012	0.059141844	0.056756509	0.066215032
4.79	0.72	2.2696	0.317237	0.025	0.07	0.165	0.3209278	0.537014923	5.00510568	0.3209278	0.537014923	0.487612536	0.568873595
4.79	0.43	2.1894	0.196401	0.025	0.07	0.165	0.13922485	0.232967725	4.62068766	0.139224845	0.232967725	0.219880345	0.256523598
4.79	0.286	1.957	0.146142	0.025	0.07	0.165	0.07603885	0.12723734	4.39857421	0.076038854	0.12723734	0.121087138	0.141266416
4.79	0.416	2.172	0.191529	0.025	0.07	0.165	0.13245501	0.221639628	4.60138219	0.132455012	0.221639628	0.209392178	0.24428757
4.79	0.417	2.122	0.196513	0.025	0.07	0.165	0.13506699	0.226010308	4.62112626	0.135066993	0.226010308	0.212151661	0.247506923
4.79	0.398	2.15	0.185116	0.025	0.07	0.165	0.12387934	0.207289779	4.57534125	0.123879337	0.207289779	0.196115203	0.228797975
4.79	0.354	2.042	0.173359	0.025	0.07	0.165	0.10546807	0.176481839	4.52557719	0.105468072	0.176481839	0.1665062	0.194254606
4.79	0.335	2.018	0.166006	0.025	0.07	0.165	0.09696462	0.162252842	4.49300253	0.096964619	0.162252842	0.153390192	0.178952803
4.79	0.40181	2.102	0.191156	0.025	0.07	0.165	0.12777096	0.213801708	4.59988945	0.127770959	0.213801708	0.200882505	0.234359752
4.79	0.34723	1.98	0.175369	0.025	0.07	0.165	0.10424886	0.174441716	4.53427717	0.104248865	0.174441716	0.16352924	0.190781532
4.79	0.33329	1.962	0.169873	0.025	0.07	0.165	0.0979619	0.163921611	4.51027756	0.097961899	0.163921611	0.153882922	0.179527647
4.79	0.30542	1.924	0.158742	0.025	0.07	0.165	0.08580484	0.143578965	4.45962276	0.085804843	0.143578965	0.135186172	0.157715067
4.79	0.57106	2.405	0.237447	0.025	0.07	0.165	0.20983547	0.351121905	4.7691813	0.209835473	0.351121905	0.330809074	0.386034247
4.79	0.48135	2.25	0.213933	0.025	0.07	0.165	0.16499319	0.276086406	4.68700912	0.164993186	0.276086406	0.259721966	0.303004861
4.79	0.46045	2.226	0.206851	0.025	0.07	0.165	0.15432635	0.258237375	4.66078363	0.154326349	0.258237375	0.24324647	0.283783709
4.79	0.37393	2.068	0.180817	0.025	0.07	0.165	0.11457844	0.191726393	4.5574581	0.114578435	0.191726393	0.18057163	0.210664051
4.79	0.34374	1.976	0.173957	0.025	0.07	0.165	0.10264668	0.17176074	4.52817544	0.102646675	0.17176074	0.161081514	0.18792589

Figure A1-1. Observed and modeled rating curves and streamflow from Site 1, West Run Watershed, Morgantown, West Virginia, U.S.A.

Table A1-3. Polynomial rating equations and R^2 values for observed and modeled rating curves at Site 1, West Run Watershed, Morgantown, WV, U.S.A.

	R² Value	Polynomial Equation
Observed Curve	0.99	$y = 4.8531x^2 - 1.4771x + 0.1128$
Manning's Curve (Obs Slope)	0.92	$y = 1.4828x^2 - 0.2545x + 0.0252$
Manning's Curve (Calc Slope)	0.92	$y = 2.4812x^2 - 0.4259x + 0.0421$
Chezy's Curve (Obs Slope)	0.92	$y = 1.4828x^2 - 0.2545x + 0.0252$
Chezy's Curve (Calc Slope)	0.92	$y = 2.4812x^2 - 0.4259x + 0.0421$
Dingman and Sharma's Curve (Obs Slope)	0.92	$y = 2.2489x^2 - 0.3577x + 0.0365$
Dingman and Sharma's Curve (Calc Slope)	0.92	$y = 2.6236x^2 - 0.4173x + 0.0425$

Table A1-4. Descriptive statistics for observed and modeled streamflow used to generate the rating curves for Site 1, West Run Watershed, Morgantown, WV, U.S.A.

	Sample Size	Mean (m³/s)	St. Dev.	SE of Mean
Observed	47	0.104	0.142	0.021
Manning's Curve (Obs Slope)	47	0.071	0.067	0.01
Manning's Curve (Calc Slope)	47	0.119	0.113	0.016
Chezy's Curve (Obs Slope)	47	0.071	0.067	0.01
Chezy's Curve (Calc Slope)	47	0.119	0.113	0.016
Dingman and Sharma's Curve (Obs Slope)	47	0.113	0.105	0.015
Dingman and Sharma's Curve (Calc Slope)	47	0.132	0.123	0.018

Table A1-5. P-values of the statistical analyses (post-hoc ANOVA) for observed and modeled rating curves at Site 1, West Run Watershed, Morgantown, WV, U.S.A.

	Observed Curve	Rating Equation Curve	Manning's Curve (Obs Slope)	Manning's Curve (Calc Slope)	Chezy's Curve (Obs Slope)	Chezy's Curve (Calc Slope)	Dingman and Sharma's Curve (Obs Slope)	Dingman and Sharma's Curve (Calc Slope)
Observed Curve	-	1	0.84	1	0.84	1	1	0.94
Rating Equation Curve	-	-	0.79	1	0.79	1	1	0.96
Manning's Curve (Obs Slope)	-	-	-	0.44	1	0.44	0.61	0.15
Manning's Curve (Calc Slope)	-	-	-	-	0.44	1	1	1
Chezy's Curve (Obs Slope)	-	-	-	-	-	0.44	0.61	0.15
Chezy's Curve (Calc Slope)	-	-	-	-	-	-	1	1
Dingman and Sharma's Curve (Obs Slope)	-	-	-	-	-	-	-	0.99
Dingman and Sharma's Curve (Calc Slope)	-	-	-	-	-	-	-	-

Figure A1-2. Box and whisker plots for the results of the statistical analyses (post-hoc ANOVA) of observed and modeled rating curves at Site 1, West Run Watershed, Morgantown, WV, U.S.A.

Figure A1-3. Cross-sectional profile of WRW Site 1, West Run Watershed, Morgantown, WV, U.S.A. (Figure 2). Channel Width of zero (0) represents the left bank facing downstream.

Figure A1-5. Photographs showing channel characteristics at Site #1, West Run Watershed, Morgantown, WV, U.S.A. Photo 1 was taken looking upstream in the channel. Photo 2 was taken from the right bank looking downstream.

APPENDIX 2: Site 2

Table A2-1. Streamflow measurements and stage collected at Site 2, West Run Watershed, Morgantown, WV, U.S.A. (Figure 2).

Date	Mean Depth of Cross-Section (m)	Stage(PT in cm)	Barometric Pressure (in cm)	Pressure Corrected Stage (cm)	Stilling Well Offset (cm)	P-Corrected Stage + Offset (cm)	P-Corrected Stage + Offset (m)	SonTec Discharge (m3/s)	Rating Equation Discharge (m3/s)
1/23/2018	0.0838	89.43	74.32	15.11	3.2	18.31	0.1831	0.0045	0.003430333
3/8/2018	0.0838	93.01	77.92	15.09	3.2	18.29	0.1829	0.0038	0.003416232
3/29/2018	0.0889	98.04	80.06	17.98	3.2	21.18	0.2118	0.0152	0.009730639
4/4/2018	0.1283	90.15	66.91	23.24	3.2	26.44	0.2644	0.0598	0.04332784
8/30/2018	0.0869	103.43	89.11	14.32	3.2	17.52	0.1752	0.0026	0.003186995
9/11/2018	0.0823	106.69	90.11	16.58	3.2	19.78	0.1978	0.0089	0.005596152
9/18/2018	0.1049	100.49	81.82	18.67	3.2	21.87	0.2187	0.0207	0.012511941
9/25/2018	0.1625	114.53	90.95	23.58	3.2	26.78	0.2678	0.0488	0.046481282
10/4/2018	0.0820	98.78	85.16	13.62	3.2	16.82	0.1682	0.0022	0.003509181
10/4/2018	0.0799	98.61	85.1	13.51	3.2	16.71	0.1671	0.0022	0.003605753
10/18/2018	0.0899	113.51	100.2	13.31	3.2	16.51	0.1651	0.0037	0.003813307
10/18/2018	0.0857	113.88	100.33	13.55	3.2	16.75	0.1675	0.0015	0.003569192
10/30/2018	0.0878	108.32	89.82	18.5	3.1	21.57	0.2157	0.0034	0.01124235
12/17/2018	0.1067	101.6	82.2	19.4	3.1	22.47	0.2247	0.0126	0.015329561
12/31/2018	0.1021	96.63	77.46	19.17	3.1	22.24	0.2224	0.0125	0.014205593
1/17/2019	0.0765	104.83	88.81	16.02	3.1	19.09	0.1909	0.0040	0.004302031
1/23/2019	0.0902	95.66	77.94	17.72	3.1	20.79	0.2079	0.0050	0.008375783
1/23/2019	0.0972	95.12	77.02	18.1	3.1	21.17	0.2117	0.0044	0.00969394
2/12/2019	0.1509	99.76	76.11	23.65	3.1	26.72	0.2672	0.0563	0.04591613
2/12/2019	0.1521	98.7	75.7	23	3.1	26.07	0.2607	0.0500	0.04003161
3/25/2019	0.0817	96.88	83.02	13.86	3.1	16.93	0.1693	0.0024	0.003425087
4/2/2019	0.0704	99.16	86.1	13.06	3.1	16.13	0.1613	0.0021	0.004321305
4/12/2019	0.0832	96	80.54	15.46	3.1	18.53	0.1853	0.0025	0.003612671
7/5/2019	0.1731	111.87	85.88	25.99	3.1	29.06	0.2906	0.0637	0.070708059
10/31/2019	0.1716	95.36	70.91	24.45	3.1	27.55	0.2755	0.0452	0.054063609
12/17/2019	0.2107	97.08	73.68	23.4	3.1	26.5	0.2650	0.0641	0.043875668
3/1/2021	0.21	1024.3	997.28	27	3.1	30.1	0.3010	0.0772	0.083539236
3/1/2021	0.211	1023.5	997.19	26.3	3.1	29.4	0.2940	0.0622	0.074780147
3/1/2021	0.209	1023.5	997.09	26.4	3.1	29.5	0.2950	0.0735	0.076000508
3/1/2021	0.199	1023.6	997.35	26.3	3.1	29.4	0.2940	0.0711	0.074780147
3/1/2021	0.2	1023.7	997.46	26.2	3.1	29.3	0.2930	0.0687	0.073570099
3/1/2021	0.201	1022.4	997.52	24.9	3.1	28	0.2800	0.0705	0.05877792
8/16/2021	0.342	1049.7	1003.71	46	3.1	49.1	0.4910	0.5136	0.51428626
8/16/2021	0.327	1048	1003.58	44.4	3.1	47.5	0.4750	0.4616	0.463657688
8/16/2021	0.293	1042.2	1003.04	39.2	3.1	42.3	0.4230	0.3046	0.317347503
8/16/2021	0.251	1039.8	1002.74	37.1	3.1	40.2	0.4020	0.2325	0.266165305
8/16/2021	0.235	1035.4	1002.61	32.8	3.1	35.9	0.3590	0.1302	0.1755538
9/1/2021	0.299	1023.9	988.06	35.8	3.1	38.9	0.3890	0.2518	0.236760172
9/1/2021	0.299	1024.4	988.02	36.4	3.1	39.5	0.3950	0.2852	0.250115208
9/1/2021	0.323	1027.3	988.01	39.3	3.1	42.4	0.4240	0.367	0.319898189
9/1/2021	0.315	1027.3	988.01	39.3	3.1	42.4	0.4240	0.3488	0.319898189
9/1/2021	0.308	1027.7	988.04	39.7	3.1	42.8	0.4280	0.3097	0.330204059
9/1/2021	0.299	1027.7	988.03	39.7	3.1	42.8	0.4280	0.3079	0.330204059

Table A2-2. Modeled streamflow at Site 2, West Run Watershed, Morgantown, WV, U.S.A.

Cross-Section Area (m ²)	A (Cross Section area of flow)	P (Wetted Perimeter)	RH=A/P Hydraulic Radius (m)	Observed Slope (m)	Calculated Slope using ArcGIS (m)	Roughness Coefficient (n)	Manning Discharge (m ³ /s) (Obs Slope)	Manning Discharge (m ³ /s) (Calc Slope)	Chezy Coefficient (C)	Chezy Discharge (m ³ /s) (Obs Slope)	Chezy Discharge (m ³ /s) (Calc Slope)	Dingman & Sharma Discharge (m ³ /s) (Obs. Slope)	Dingman & Sharma Discharge (m ³ /s) (Calc Slope)
3.28	0.170	1.8176	0.093361354	0.061	0.11	0.14	0.061608467	0.082731676	4.810975601	0.061608467	0.082731676	0.062889454	0.067421054
3.28	0.169	1.8168	0.093223501	0.061	0.11	0.14	0.061432045	0.082494767	4.809790931	0.061432045	0.082494767	0.062713651	0.067232583
3.28	0.215	1.9196	0.112257697	0.061	0.11	0.14	0.088465848	0.118797436	4.961061977	0.088465848	0.118797436	0.089602216	0.096058647
3.28	0.299	2.0882	0.143390475	0.061	0.11	0.14	0.144714383	0.194331464	5.167637188	0.144714383	0.194331464	0.145352649	0.155826266
3.28	0.099	1.3168	0.07518226	0.061	0.11	0.14	0.031111121	0.041777946	4.640426096	0.031111121	0.041777946	0.0306512	0.032859821
3.28	0.094	1.3078	0.071876434	0.061	0.11	0.14	0.028667451	0.038496435	4.605778531	0.028667451	0.038496435	0.028329234	0.030370542
3.28	0.128	1.427	0.089698669	0.061	0.11	0.14	0.0452485	0.060762496	4.778991929	0.0452485	0.060762496	0.044462404	0.047666213
3.28	0.21	1.62	0.12962963	0.061	0.11	0.14	0.094891147	0.127425728	5.081469748	0.094891147	0.127425728	0.092080187	0.098715171
3.28	0.094	1.307	0.071920428	0.061	0.11	0.14	0.028679148	0.038512142	4.606248269	0.028679148	0.038512142	0.028336168	0.030377976
3.28	0.091	1.3026	0.069860279	0.061	0.11	0.14	0.027231098	0.03656761	4.583990238	0.027231098	0.03656761	0.026963044	0.02890591
3.28	0.109	1.3986	0.077935078	0.061	0.11	0.14	0.035084775	0.047114016	4.668321884	0.035084775	0.047114016	0.034810937	0.037319295
3.28	0.105	1.3904	0.075517837	0.061	0.11	0.14	0.033094758	0.044441697	4.643871789	0.033094758	0.044441697	0.032900016	0.035270679
3.28	0.1	1.3182	0.075861023	0.061	0.11	0.14	0.031614235	0.042453559	4.647382444	0.031614235	0.042453559	0.031126388	0.033369249
3.28	0.122	1.3564	0.089943969	0.061	0.11	0.14	0.043206068	0.058019792	4.781167653	0.043206068	0.058019792	0.042073646	0.04510533
3.28	0.132	1.4994	0.088035214	0.061	0.11	0.14	0.046083816	0.06188421	4.76410548	0.046083816	0.06188421	0.045275233	0.049049519
3.28	0.087	1.296	0.06712963	0.061	0.11	0.14	0.025351226	0.034043201	4.5536293	0.025351226	0.034043201	0.025173467	0.026987381
3.28	0.11	1.3994	0.078605116	0.061	0.11	0.14	0.035609301	0.047818381	4.67498728	0.035609301	0.047818381	0.035306543	0.037850612
3.28	0.118	1.4134	0.083486628	0.061	0.11	0.14	0.03976462	0.053398402	4.722168187	0.03976462	0.053398402	0.039722234	0.042102058
3.28	0.242	1.9018	0.12724787	0.061	0.11	0.14	0.108007172	0.145038741	5.065788473	0.108007172	0.145038741	0.107943596	0.115721643
3.28	0.243	1.904	0.12762605	0.061	0.11	0.14	0.108668259	0.145926489	5.068294621	0.108668259	0.145926489	0.108595827	0.116420873
3.28	0.093	1.306	0.071209801	0.061	0.11	0.14	0.028186837	0.037851036	4.598631321	0.028186837	0.037851036	0.027871969	0.029880328
3.28	0.092	1.2838	0.071662253	0.061	0.11	0.14	0.02800174	0.037602476	4.603488264	0.02800174	0.037602476	0.027590562	0.029578644
3.28	0.095	1.3096	0.072541234	0.061	0.11	0.14	0.029150798	0.039145502	4.612851292	0.029150798	0.039145502	0.028788896	0.030863326
3.28	0.264	1.87	0.141176471	0.061	0.11	0.14	0.126274509	0.169569256	5.15425243	0.126274509	0.169569256	0.124614214	0.133593489
3.28	0.275	1.9432	0.141519144	0.061	0.11	0.14	0.13174871	0.176920352	5.15633545	0.13174871	0.176920352	0.130853268	0.140282109
3.28	0.321	1.9454	0.165004626	0.061	0.11	0.14	0.170361973	0.228772641	5.289987565	0.170361973	0.228772641	0.166820761	0.178841297
3.28	0.316	1.9386	0.16300423	0.061	0.11	0.14	0.166350157	0.223385325	5.279244507	0.166350157	0.223385325	0.162979786	0.174723555
3.28	0.321	1.9454	0.165004626	0.061	0.11	0.14	0.170361973	0.228772641	5.289987565	0.170361973	0.228772641	0.166820761	0.178841297
3.28	0.302	1.865	0.161930295	0.061	0.11	0.14	0.158281162	0.212549777	5.273431578	0.158281162	0.212549777	0.154134775	0.165241202
3.28	0.288	1.8458	0.156029906	0.061	0.11	0.14	0.147254282	0.197742199	5.240908836	0.147254282	0.197742199	0.143638802	0.153988925
3.28	0.275	1.7728	0.155121841	0.061	0.11	0.14	0.140061318	0.18808304	5.235812948	0.140061318	0.18808304	0.135746199	0.145527607
3.28	0.26	1.6966	0.153247672	0.061	0.11	0.14	0.131352846	0.176388762	5.225216367	0.131352846	0.176388762	0.126486023	0.135600175
3.28	0.57251	2.36	0.242588983	0.061	0.11	0.14	0.392856559	0.527552193	5.640926963	0.392856559	0.527552193	0.383662388	0.411307793
3.28	0.53652	2.292	0.23408377	0.061	0.11	0.14	0.35950395	0.482764238	5.607472875	0.35950395	0.482764238	0.350488721	0.375743745
3.28	0.48019	2.224	0.21591277	0.061	0.11	0.14	0.30488464	0.409418036	5.532460889	0.30488464	0.409418036	0.297940922	0.319409531
3.28	0.41052	2.14	0.191831776	0.061	0.11	0.14	0.240889701	0.323481656	5.424487617	0.240889701	0.323481656	0.236445266	0.253482707
3.28	0.37626	2.07	0.181768116	0.061	0.11	0.14	0.212995324	0.286023354	5.37598748	0.212995324	0.286023354	0.208917978	0.223971895
3.28	0.52374	2.351	0.222773288	0.061	0.11	0.14	0.339542938	0.455959351	5.561378882	0.339542938	0.455959351	0.334032912	0.358102186
3.28	0.52432	2.351	0.223019991	0.061	0.11	0.14	0.340169864	0.456801226	5.562404873	0.340169864	0.456801226	0.334614973	0.358726188
3.28	0.57774	2.437	0.237070168	0.061	0.11	0.14	0.390409692	0.524266389	5.619333172	0.390409692	0.524266389	0.384223708	0.411909559
3.28	0.56439	2.421	0.233122677	0.061	0.11	0.14	0.377142845	0.506450842	5.603629132	0.377142845	0.506450842	0.371327904	0.398084528
3.28	0.55074	2.407	0.228807644	0.061	0.11	0.14	0.363466053	0.488084797	5.58620736	0.363466053	0.488084797	0.358129292	0.383934869
3.28	0.52316	2.351	0.222526584	0.061	0.11	0.14	0.338916475	0.455118098	5.560351945	0.338916475	0.455118098	0.333451221	0.357478581

Figure A2-1. Observed and modeled rating curves and streamflow from Site 2, West Run Watershed, Morgantown, West Virginia, U.S.A

Table A2-3. Polynomial rating equations and R^2 values for observed and modeled rating curves at Site 2, West Run Watershed, Morgantown, WV, U.S.A.

	R² Value	Polynomial Equation
Observed Curve	0.99	$y = 5.1563x^2 - 1.8167x + 0.1632$
Manning's Curve (Obs Slope)	0.95	$y = 1.015x^2 + 0.6122x - 0.1125$
Manning's Curve (Calc Slope)	0.95	$y = 1.363x^2 + 0.8221x - 0.1511$
Chezy's Curve (Obs Slope)	0.95	$y = 1.015x^2 + 0.6122x - 0.1125$
Chezy's Curve (Calc Slope)	0.95	$y = 1.363x^2 + 0.8221x - 0.1511$
Dingman and Sharma's Curve (Obs Slope)	0.94	$y = 0.9841x^2 + 0.605x - 0.1103$
Dingman and Sharma's Curve (Calc Slope)	0.94	$y = 1.055x^2 + 0.6486x - 0.1182$

Table A2-4. Descriptive statistics for observed and modeled streamflow used to generate the rating curves for Site 2, West Run Watershed, Morgantown, WV, U.S.A.

	Sample Size	Mean (m³/s)	St. Dev.	SE of Mean
Observed	43	0.103	0.140	0.021
Manning's Curve (Obs Slope)	43	0.144	0.124	0.019
Manning's Curve (Calc Slope)	43	0.193	0.167	0.025
Chezy's Curve (Obs Slope)	43	0.144	0.124	0.019
Chezy's Curve (Calc Slope)	43	0.193	0.167	0.025
Dingman and Sharma's Curve (Obs Slope)	43	0.142	0.122	0.019
Dingman and Sharma's Curve (Calc Slope)	43	0.152	0.130	0.020

Table A2-5. P-values of the statistical analyses (post-hoc ANOVA) for observed and modeled rating curves at Site 2, West Run Watershed, Morgantown, WV, U.S.A.

	Observed Curve	Rating Equation Curve	Manning's Curve (Obs Slope)	Manning's Curve (Calc Slope)	Chezy's Curve (Obs Slope)	Chezy's Curve (Calc Slope)	Dingman and Sharma's Curve (Obs Slope)	Dingman and Sharma's Curve (Calc Slope)
Observed Curve	-	1	0.87	0.06	0.87	0.06	0.91	0.74
Rating Equation Curve	-	-	0.87	0.06	0.87	0.06	0.91	0.74
Manning's Curve (Obs Slope)	-	-	-	0.73	1	0.73	1	1
Manning's Curve (Calc Slope)	-	-	-	-	0.73	1	0.68	0.87
Chezy's Curve (Obs Slope)	-	-	-	-	-	0.73	1	1
Chezy's Curve (Calc Slope)	-	-	-	-	-	-	0.68	0.87
Dingman and Sharma's Curve (Obs Slope)	-	-	-	-	-	-	-	1
Dingman and Sharma's Curve (Calc Slope)	-	-	-	-	-	-	-	-

Figure A2-2. Box and whisker plots for the results of the statistical analyses (post-hoc ANOVA) of observed and modeled rating curves at Site 2, West Run Watershed, Morgantown, WV, U.S.A.

Figure A2-3. Cross-sectional profile of WRW Site 2, West Run Watershed, Morgantown, WV, USA (Figure 2). Channel Width of zero (0) represents the left bank facing downstream.

Figure A2-4. Plan view profile of WRW Site 2, West Run Watershed, Morgantown, WV, U.S.A. (Figure 2). Showing the positioning of stilling well in relation to where the streamflow was measured. Along with the channel width at the stilling well, point where cross-sections were performed, and 6.0m upstream and downstream from the stilling well.

Figure A2-5. Photographs showing channel characteristics at Site #2, West Run Watershed, Morgantown, WV, U.S.A. Photo 1 was taken looking upstream in the channel. Photo 2 was taken from the left bank looking downstream.

APPENDIX 3: Site 3

Table A3-1. Streamflow measurements and stage collected at Site 3, West Run Watershed, Morgantown, WV, U.S.A. (Figure 2).

Date	Mean Depth of Cross-Section (m)	Stage(PT in cm)	Barometric Pressure (in cm)	Pressure Corrected Stage (cm)	Stilling Well Offset (cm)	P-Corrected Stage + Offset (cm)	P-Corrected Stage + Offset (m)	SonTec Discharge (m3/s)	Rating Equation Discharge (m3/s)
1/23/2018	0.1490	91.87	74.32	17.55	2.2	19.75	0.1975	0.0706	0.10604525
3/8/2018	0.1208	91.11	77.95	13.16	2.2	15.36	0.1536	0.0263	0.05802304
3/14/2018	0.0868	91.04	79.86	11.18	2.2	13.38	0.1338	0.0197	0.03636382
3/29/2018	0.1861	102.44	80.2	22.24	2.2	24.44	0.2444	0.0892	0.15734916
4/4/2018	0.2777	110.29	75.96	34.33	2.2	36.53	0.3653	0.2354	0.28960167
9/11/2018	0.1771	106.01	90.25	15.76	2.2	17.96	0.1796	0.0497	0.08646444
9/18/2018	0.1652	101.78	81.73	20.05	2.2	22.25	0.2225	0.0851	0.13339275
9/25/2018	0.2929	119.8	90.47	29.33	2.2	31.53	0.3153	0.1763	0.23490667
10/4/2018	0.1445	94.11	84.93	9.18	2.2	11.38	0.1138	0.0105	0.01448582
10/18/2018	0.1518	109.87	100.34	9.53	2.2	11.73	0.1173	0.0102	0.01831447
10/18/2018	0.1475	109.83	100.27	9.56	2.2	11.76	0.1176	0.0113	0.01864264
12/4/2018	0.1628	100.72	85.38	15.34	3.9	19.21	0.1921	0.0356	0.10013819
1/17/2019	0.1524	101.52	88.75	12.77	3.9	16.64	0.1664	0.0187	0.07202496
1/17/2019	0.1259	101.62	88.86	12.76	3.9	16.63	0.1663	0.0109	0.07191557
1/23/2019	0.1786	92.67	76.96	15.71	3.9	19.58	0.1958	0.0315	0.10418562
1/23/2019	0.1670	92.48	76.74	15.74	3.9	19.61	0.1961	0.0354	0.10451379
2/12/2019	0.2874	104.94	75.42	29.52	3.9	33.39	0.3339	0.2239	0.25525321
4/2/2019	0.1448	96.51	85.96	10.55	3.9	14.42	0.1442	0.0095	0.04774038
4/12/2019	0.1597	96.25	81.08	15.17	3.9	19.04	0.1904	0.0278	0.09827856
7/5/2019	0.3042	118.37	85.91	32.46	3.9	36.33	0.3633	0.2392	0.28741387
10/31/2019	0.2709	105.12	70.73	34.39	3.9	38.29	0.3829	0.2536	0.30885431
12/10/2019	0.1941	113.69	78.89	34.8	3.9	38.7	0.387	0.2362	0.3133393
12/17/2019	0.3114	118.61	73.81	44.8	3.9	48.7	0.487	0.3745	0.4227293
2/13/2020	0.2889	1030.7	991.66	39	3.9	42.9	0.429	0.2947	0.3592831
11/11/2020	0.24	1019.2	996.52	22.7	3.9	26.6	0.266	0.0985	0.1809774
8/16/2021	0.377	1083.7	1002.65	81	3.9	84.9	0.849	0.7467	0.8187211
8/16/2021	0.346	1090.8	1002.63	88.2	3.9	92.1	0.921	0.9017	0.8974819
8/16/2021	0.328	1075.7	1002.49	73.2	3.9	77.1	0.771	0.6703	0.7333969
8/16/2021	0.306	1075.4	1002.25	73.1	3.9	77	0.77	0.6978	0.732303
8/16/2021	0.303	1063.2	1002.37	60.8	3.9	64.7	0.647	0.5168	0.5977533

Table A3-2. Modeled streamflow at Site 3, West Run Watershed, Morgantown, WV, U.S.A.

Cross-Section Area (m ²)	A (Cross Section area of flow)	P (Wetted Perimeter)	RH=A/P Hydraulic Radius (m)	Observed Slope (m)	Calculated Slope using ArcGIS (m)	Roughness Coefficient (n)	Manning Discharge (m ³ /s) (Obs Slope)	Manning Discharge (m ³ /s) (Calc Slope)	Chezy Coefficient (C)	Chezy Discharge (m ³ /s) (Obs Slope)	Chezy Discharge (m ³ /s) (Calc Slope)	Dingman & Sharma Discharge (m ³ /s) (Obs. Slope)	Dingman & Sharma Discharge (m ³ /s) (Calc Slope)
6.93	0.193	1.8697	0.103052	0.03	0.04	0.13	0.056424639	0.065153561	5.267029121	0.056424639	0.065153561	0.068330785	0.071520699
6.93	0.123	1.7053	0.071902	0.03	0.04	0.13	0.028247964	0.032617939	4.960361422	0.028247964	0.032617939	0.034822788	0.036448435
6.93	0.091	1.6258	0.055985	0.03	0.04	0.13	0.017747014	0.020492487	4.757751798	0.017747014	0.020492487	0.022212183	0.023249123
6.93	0.268	2.0269	0.131981	0.03	0.04	0.13	0.092392699	0.106685899	5.488773483	0.092392699	0.106685899	0.110863277	0.116038753
6.93	0.460	2.3450	0.196351	0.03	0.04	0.13	0.207245214	0.23930616	5.864470978	0.207245214	0.23930616	0.24571291	0.257183627
6.93	0.553	3.478	0.158999	0.03	0.04	0.13	0.216241698	0.249694405	5.661818024	0.216241698	0.249694405	0.279950456	0.293019498
6.93	0.629	4.14	0.151932	0.03	0.04	0.13	0.238617041	0.275531226	5.619077625	0.238617041	0.275531226	0.319730235	0.334656333
6.93	0.767	4.0146	0.191053	0.03	0.04	0.13	0.338985687	0.391426955	5.83779484	0.338985687	0.391426955	0.442214088	0.46285815
6.93	0.341	2.651	0.128631	0.03	0.04	0.13	0.115771436	0.13368134	5.46530105	0.115771436	0.13368134	0.145869712	0.152679408
6.93	0.347	2.5892	0.134018	0.03	0.04	0.13	0.121075425	0.139805858	5.502802937	0.121075425	0.139805858	0.151348598	0.158414067
6.93	0.337	2.5812	0.130559	0.03	0.04	0.13	0.115554272	0.13343058	5.478874532	0.115554272	0.13343058	0.144723664	0.151479859
6.93	0.459	3.1442	0.145983	0.03	0.04	0.13	0.169550201	0.195779708	5.581793103	0.169550201	0.195779708	0.21743711	0.227587816
6.93	0.43	3.1238	0.137653	0.03	0.04	0.13	0.152736401	0.176364805	5.527399482	0.152736401	0.176364805	0.196733796	0.205918
6.93	0.354	3.0704	0.115294	0.03	0.04	0.13	0.111727327	0.129011604	5.36650286	0.111727327	0.129011604	0.145884962	0.15269537
6.93	0.531	3.3292	0.159498	0.03	0.04	0.13	0.208072596	0.240261539	5.664771811	0.208072596	0.240261539	0.267266241	0.279743141
6.93	0.509	3.382	0.150503	0.03	0.04	0.13	0.191880648	0.221564688	5.610230147	0.191880648	0.221564688	0.248487192	0.260087422
6.93	0.842	4.08	0.206373	0.03	0.04	0.13	0.391769527	0.452376484	5.913328	0.391769527	0.452376484	0.50881304	0.532566168
6.93	0.374	2.8796	0.129879	0.03	0.04	0.13	0.127795384	0.147565399	5.474106224	0.127795384	0.147565399	0.16319263	0.170811019
6.93	0.449	3.2022	0.140216	0.03	0.04	0.13	0.161458981	0.186436773	5.544422224	0.161458981	0.186436773	0.208502128	0.218235718
6.93	0.877	4.0372	0.21723	0.03	0.04	0.13	0.422243612	0.487564926	5.96407646	0.422243612	0.487564926	0.54476931	0.570200999
6.93	0.908	3.8948	0.233131	0.03	0.04	0.13	0.458251169	0.529142872	6.034714967	0.458251169	0.529142872	0.583688791	0.610937375
6.93	0.799	4.5032	0.177429	0.03	0.04	0.13	0.336135527	0.388135874	5.766260233	0.336135527	0.388135874	0.450405793	0.471432272
6.93	1.068	4.0518	0.263587	0.03	0.04	0.13	0.584975076	0.675471036	6.159477264	0.584975076	0.675471036	0.741634217	0.776256232
6.93	0.976	4.0828	0.239052	0.03	0.04	0.13	0.500873706	0.578359138	6.059990355	0.500873706	0.578359138	0.641693587	0.671650033
6.93	0.629	3.6804	0.170905	0.03	0.04	0.13	0.258090292	0.298016999	5.73036895	0.258090292	0.298016999	0.335139668	0.350785131
6.93	1.4993	4.564	0.328506	0.03	0.04	0.13	0.951045043	1.098172223	6.389699955	0.951045043	1.098172223	1.205704271	1.261990658
6.93	1.6643	4.502	0.36968	0.03	0.04	0.13	1.142175841	1.318871059	6.516699094	1.142175841	1.318871059	1.42870153	1.49539819
6.93	1.3672	4.466	0.306135	0.03	0.04	0.13	0.827417837	0.955419821	6.315031718	0.827417837	0.955419821	1.051968426	1.1010779
6.93	1.16593	4.422	0.263666	0.03	0.04	0.13	0.638742153	0.737555908	6.159785713	0.638742153	0.737555908	0.822119008	0.860498327
6.93	1.15548	4.416	0.261658	0.03	0.04	0.13	0.62979898	0.727229222	6.15194167	0.62979898	0.727229222	0.810998516	0.848858692

Figure A3-1. Observed and modeled rating curves and streamflow from Site 3, West Run Watershed, Morgantown, West Virginia, U.S.A

Table A3-3. Polynomial rating equations and R^2 values for observed and modeled rating curves at Site 3, West Run Watershed, Morgantown, WV, U.S.A.

	R² Value	Polynomial Equation
Observed Curve	0.99	$y = 0.2855x^2 + 0.8084x - 0.11$
Manning's Curve (Obs Slope)	0.87	$y = -0.5839x^2 + 1.6111x - 0.1058$
Manning's Curve (Calc Slope)	0.87	$y = -0.6742x^2 + 1.8604x - 0.1222$
Chezy's Curve (Obs Slope)	0.87	$y = -0.5839x^2 + 1.6111x - 0.1058$
Chezy's Curve (Calc Slope)	0.87	$y = -0.6742x^2 + 1.8604x - 0.1222$
Dingman and Sharma's Curve (Obs Slope)	0.87	$y = -0.7748x^2 + 2.0814x - 0.1385$
Dingman and Sharma's Curve (Calc Slope)	0.87	$y = -0.811x^2 + 2.1786x - 0.145$

Table A3-4. Descriptive statistics for observed and modeled streamflow used to generate the rating curves for Site 3, West Run Watershed, Morgantown, WV, U.S.A.

	Sample Size	Mean (m³/s)	St. Dev.	SE of Mean
Observed	30	0.207	0.254	0.046
Manning's Curve (Obs Slope)	30	0.336	0.265	0.048
Manning's Curve (Calc Slope)	30	0.388	0.306	0.056
Chezy's Curve (Obs Slope)	30	0.336	0.265	0.048
Chezy's Curve (Calc Slope)	30	0.388	0.306	0.056
Dingman and Sharma's Curve (Obs Slope)	30	0.429	0.338	0.062
Dingman and Sharma's Curve (Calc Slope)	30	0.449	0.354	0.065

Table A3-5. P-values of the statistical analyses (post-hoc ANOVA) for observed and modeled rating curves at Site 3, West Run Watershed, Morgantown, WV, U.S.A.

	Observed Curve	Rating Equation Curve	Manning's Curve (Obs Slope)	Manning's Curve (Calc Slope)	Chezy's Curve (Obs Slope)	Chezy's Curve (Calc Slope)	Dingman and Sharma's Curve (Obs Slope)	Dingman and Sharma's Curve (Calc Slope)
Observed Curve	-	1	0.69	0.26	0.69	0.26	0.07	0.04*
Rating Equation Curve	-	-	0.96	0.66	0.96	0.66	0.31	0.18
Manning's Curve (Obs Slope)	-	-	-	1	1	1	1	0.82
Manning's Curve (Calc Slope)	-	-	-	-	1	1	0.93	1
Chezy's Curve (Obs Slope)	-	-	-	-	-	1	1	0.82
Chezy's Curve (Calc Slope)	-	-	-	-	-	-	1	1
Dingman and Sharma's Curve (Obs Slope)	-	-	-	-	-	-	-	1
Dingman and Sharma's Curve (Calc Slope)	-	-	-	-	-	-	-	-

*= indicates that the difference of the means is significant at the 0.05 level.

Figure A3-2. Box and whisker plots for the results of the statistical analyses (post-hoc ANOVA) of observed and modeled rating curves at Site 3, West Run Watershed, Morgantown, WV, U.S.A.

Figure A3-3. Cross-sectional profile of WRW Site 3, West Run Watershed, Morgantown, WV, USA (Figure 2). Channel Width of zero (0) represents the left bank facing downstream.

Figure A3-4. Plan view profile of WRW Site 3, West Run Watershed, Morgantown, WV, U.S.A. (Figure 2). Showing the positioning of stilling well in relation to where the streamflow was measured. Along with the channel width at the stilling well, point where cross-sections were performed, and 6.0m upstream and downstream from the stilling well.

Figure A3-5. Photographs showing channel characteristics at Site #3, West Run Watershed, Morgantown, WV, U.S.A. Photo 1 was taken looking upstream in the channel. Photo 2 was taken from the left bank looking downstream

APPENDIX 4: Site 4

Table A4-1. Streamflow measurements and stage collected at Site 4, West Run Watershed, Morgantown, WV, U.S.A. (Figure 2).

Date	Mean Depth of Cross-Section (m)	Stage(PT in cm)	Barometric Pressure (in cm)	Pressure Corrected Stage (cm)	Stilling Well Offset (cm)	P-Corrected Stage + Offset (cm)	P-Corrected Stage + Offset (m)	SonTec Discharge (m3/s)	Rating Equation Discharge (m3/s)
1/2/2018	0.0986	129.15	103.5	25.65	4.2	29.85	0.2985	0.0096	0.016758889
4/20/2018	0.1333	130.11	96.94	33.17	4.2	37.37	0.3737	0.0767	0.070323763
7/16/2018	0.1439	105.91	83.24	22.67	4.2	26.87	0.2687	0.0035	0.003750076
7/23/2018	0.1341	103.38	80.92	22.46	4.2	26.66	0.2666	0.0046	0.003009283
7/23/2018	0.1466	103.38	81.01	22.37	4.2	26.57	0.2657	0.0040	0.002698892
7/25/2018	0.1680	105.73	82.67	23.06	4.2	27.26	0.2726	0.0085	0.005187289
8/30/2018	0.1667	115.78	89.07	26.71	4.2	30.91	0.3091	0.0118	0.022510872
9/11/2018	0.2597	125.1	90.06	35.04	4.2	39.24	0.3924	0.0801	0.088255351
9/18/2018	0.3335	121.67	81.49	40.18	4.2	44.38	0.4438	0.1557	0.147006171
9/25/2018	0.3679	141.17	89.45	51.72	4.2	55.92	0.5592	0.3637	0.329462676
10/4/2018	0.2112	110.52	85.07	25.45	4.2	29.65	0.2965	0.0231	0.015739792
10/4/2018	0.1975	110.37	84.97	25.4	4.2	29.6	0.2960	0.0241	0.015488301
10/18/2018	0.2012	127.14	100.19	26.95	4.2	31.15	0.3115	0.0148	0.023895148
10/18/2018	0.2091	127.01	100.28	26.73	4.2	30.93	0.3093	0.0150	0.022625073
10/30/2018	0.2548	122.69	89.87	32.82	4.2	37.02	0.3702	0.0503	0.067171647
12/4/2018	0.2173	116.57	85.35	31.22	4.2	35.42	0.3542	0.0352	0.05358138
12/17/2018	0.2725	119.51	82.87	36.64	4.2	40.84	0.4084	0.1026	0.105056008
1/23/2019	0.2387	108.32	76.44	31.88	4.2	36.08	0.3608	0.0740	0.05902443
1/23/2019	0.2381	108.37	76.67	31.7	4.2	35.9	0.3590	0.0750	0.05751727
4/2/2019	0.1652	110.58	85.73	24.85	4.2	29.05	0.2905	0.0156	0.012808564
4/12/2019	0.2228	111.96	81.82	30.14	4.2	34.34	0.3434	0.0468	0.045168106
4/12/2019	0.2170	109.97	82.03	27.94	4.2	32.14	0.3214	0.0409	0.029925092
12/10/2019	0.3005	129.07	79.47	49.6	4.2	53.8	0.5380	0.2857	0.290698977
12/17/2019	0.3716	139.52	74.82	64.7	4.2	68.9	0.6890	0.6114	0.618273862
10/16/2021	0.3730	1043.30	991.92	51.38	4.2	55.58	0.5558	0.3115	0.323086913
10/16/2021	0.3460	1042.10	991.80	50.3	4.2	54.5	0.5450	0.3033	0.303237258
10/16/2021	0.3440	1041.80	991.98	49.82	4.2	54.02	0.5402	0.3041	0.294611846
10/16/2021	0.3460	1040.30	992.13	48.17	4.2	52.37	0.5237	0.2723	0.265885006
10/16/2021	0.3280	1038.80	991.99	46.81	4.2	51.01	0.5101	0.2473	0.243282229
10/16/2021	0.3270	1038.30	992.20	46.1	4.2	50.3	0.5030	0.2240	0.231868237
10/16/2021	0.3140	1038.30	992.45	45.85	4.2	50.05	0.5005	0.2202	0.227912257
10/16/2021	0.3250	1038.00	992.38	45.62	4.2	49.82	0.4982	0.2089	0.224301749
10/16/2021	0.3130	1037.60	992.38	45.22	4.2	49.42	0.4942	0.2157	0.218088789

Table A4-2. Modeled streamflow at Site 4, West Run Watershed, Morgantown, WV, U.S.A.

Cross-Section Area (m ²)	A (Cross Section area of flow)	P (Wetted Perimeter)	RH=A/P Hydraulic Radius (m)	Observed Slope (m)	Calculated Slope using ArcGIS (m)	Roughness Coefficient (n)	Manning Discharge (m ³ /s) (Obs Slope)	Manning Discharge (m ³ /s) (Calc Slope)	Chezy Coefficient (C)	Chezy Discharge (m ³ /s) (Obs Slope)	Chezy Discharge (m ³ /s) (Calc Slope)	Dingman & Sharma Discharge (m ³ /s) (Obs. Slope)	Dingman & Sharma Discharge (m ³ /s) (Calc Slope)
2.61	0.354	2.1848	0.161958	0.01	0.033	0.127	0.082784021	0.150384642	5.813399566	0.082784021	0.150384642	0.135380992	0.16966021
2.61	0.366	3.0096	0.121611	0.01	0.033	0.127	0.070738998	0.128503771	5.542320846	0.070738998	0.128503771	0.125599811	0.157402379
2.61	0.285	2.2688	0.125617	0.01	0.033	0.127	0.056286845	0.102250131	5.572341447	0.056286845	0.102250131	0.094883179	0.118908127
2.61	0.245	2.0972	0.116822	0.01	0.033	0.127	0.046101302	0.083747173	5.505337966	0.046101302	0.083747173	0.077186093	0.09673004
2.61	0.268	2.1224	0.126272	0.01	0.033	0.127	0.053113238	0.096484988	5.577174143	0.053113238	0.096484988	0.088463045	0.110862379
2.61	0.307	2.1646	0.141828	0.01	0.033	0.127	0.065741832	0.119425969	5.686212241	0.065741832	0.119425969	0.108681182	0.13619986
2.61	0.305	2.1624	0.141047	0.01	0.033	0.127	0.065073673	0.118212198	5.680984183	0.065073673	0.118212198	0.107613308	0.134861595
2.61	0.475	2.3486	0.202248	0.01	0.033	0.127	0.128868347	0.234100978	6.032681142	0.128868347	0.234100978	0.20902834	0.26192351
2.61	0.661	2.648	0.249622	0.01	0.033	0.127	0.206341567	0.374838071	6.248036033	0.206341567	0.374838071	0.335001269	0.419825449
2.61	0.813	2.968	0.273922	0.01	0.033	0.127	0.270004659	0.49048782	6.345522483	0.270004659	0.49048782	0.443224357	0.555451222
2.61	0.402	2.3272	0.17274	0.01	0.033	0.127	0.098178689	0.178350446	5.876178816	0.098178689	0.178350446	0.161343267	0.202196277
2.61	0.376	2.3	0.163478	0.01	0.033	0.127	0.088516479	0.160798169	5.822456875	0.088516479	0.160798169	0.145920428	0.18286829
2.61	0.368	2.2316	0.164904	0.01	0.033	0.127	0.087136158	0.158290692	5.83089011	0.087136158	0.158290692	0.142780476	0.178933285
2.61	0.382	2.2472	0.169989	0.01	0.033	0.127	0.092301211	0.167673477	5.860480409	0.092301211	0.167673477	0.150996099	0.189229149
2.61	0.466	2.3386	0.199265	0.01	0.033	0.127	0.125180162	0.227401057	6.017756458	0.125180162	0.227401057	0.203154019	0.254593743
2.61	0.397	2.2634	0.1754	0.01	0.033	0.127	0.097950408	0.177935752	5.891164434	0.097950408	0.177935752	0.159966739	0.200471205
2.61	0.498	2.3738	0.20979	0.01	0.033	0.127	0.138446644	0.251500819	6.069605742	0.138446644	0.251500819	0.22418206	0.280946201
2.61	0.437	2.3066	0.189456	0.01	0.033	0.127	0.113505563	0.206193096	5.967344864	0.113505563	0.206193096	0.18463972	0.231391522
2.61	0.435	2.305	0.18872	0.01	0.033	0.127	0.112693211	0.204717384	5.963474047	0.112693211	0.204717384	0.183363115	0.229791673
2.61	0.302	2.1596	0.139841	0.01	0.033	0.127	0.064065709	0.11638114	5.672857613	0.064065709	0.11638114	0.106007927	0.132849722
2.61	0.408	2.2748	0.179356	0.01	0.033	0.127	0.10217259	0.185605728	5.913107433	0.10217259	0.185605728	0.166658665	0.208857563
2.61	0.398	2.2732	0.175084	0.01	0.033	0.127	0.098079061	0.178169463	5.889392738	0.098079061	0.178169463	0.160323713	0.200918566
2.61	0.641	2.7348	0.234386	0.01	0.033	0.127	0.191870974	0.348550934	6.182797492	0.191870974	0.348550934	0.315104206	0.394890339
2.61	0.991	3.4102	0.290599	0.01	0.033	0.127	0.34234643	0.621903174	6.408335586	0.34234643	0.621903174	0.572464641	0.717415864
2.61	0.85239	3.032	0.281131	0.01	0.033	0.127	0.28803199	0.523236093	6.373057016	0.28803199	0.523236093	0.473411919	0.593282444
2.61	0.76355	2.902	0.263112	0.01	0.033	0.127	0.246865543	0.448453529	6.303082012	0.246865543	0.448453529	0.405192263	0.507789191
2.61	0.76064	2.898	0.262471	0.01	0.033	0.127	0.245525135	0.446018557	6.300520208	0.245525135	0.446018557	0.402988094	0.505026914
2.61	0.73858	2.826	0.261352	0.01	0.033	0.127	0.237726399	0.431851451	6.296035624	0.237726399	0.431851451	0.388648702	0.487056709
2.61	0.68806	2.752	0.250022	0.01	0.033	0.127	0.215017848	0.390599318	6.249701275	0.215017848	0.390599318	0.351369098	0.440337703
2.61	0.68545	2.75	0.249255	0.01	0.033	0.127	0.213763779	0.388321188	6.246500708	0.213763779	0.388321188	0.349376407	0.437840451
2.61	0.64684	2.685	0.240909	0.01	0.033	0.127	0.197194531	0.358221655	6.211145583	0.197194531	0.358221655	0.321990091	0.403519768
2.61	0.6689	2.707	0.2471	0.01	0.033	0.127	0.207398734	0.376758511	6.23746951	0.207398734	0.376758511	0.338325403	0.423991272
2.61	0.64451	2.683	0.24022	0.01	0.033	0.127	0.196109484	0.35625057	6.208182048	0.196109484	0.35625057	0.320262976	0.401355338

Figure A4-1. Observed and modeled rating curves and streamflow from Site 4, West Run Watershed, Morgantown, West Virginia, U.S.A

Table A4-3. Polynomial rating equations and R^2 values for observed and modeled rating curves at Site 4, West Run Watershed, Morgantown, WV, U.S.A.

	R² Value	Polynomial Equation
Observed Curve	0.99	$y = 2.6263x^2 - 1.0531x + 0.0971$
Manning's Curve (Obs Slope)	0.95	$y = 0.4886x^2 + 0.8166x - 0.1505$
Manning's Curve (Calc Slope)	0.95	$y = 0.2689x^2 + 0.4495x - 0.0828$
Chezy's Curve (Obs Slope)	0.95	$y = 0.4886x^2 + 0.8166x - 0.1505$
Chezy's Curve (Calc Slope)	0.95	$y = 0.2689x^2 + 0.4495x - 0.0828$
Dingman and Sharma's Curve (Obs Slope)	0.95	$y = 0.6055x^2 + 0.598x - 0.1082$
Dingman and Sharma's Curve (Calc Slope)	0.95	$y = 0.7589x^2 + 0.7494x - 0.1356$

Table A4-4. Descriptive statistics for observed and modeled streamflow used to generate the rating curves for Site 4, West Run Watershed, Morgantown, WV, U.S.A.

	Sample Size	Mean (m³/s)	St. Dev.	SE of Mean
Observed	33	0.135	0.144	0.025
Manning's Curve (Obs Slope)	33	0.147	0.08	0.014
Manning's Curve (Calc Slope)	33	0.267	0.145	0.025
Chezy's Curve (Obs Slope)	33	0.147	0.08	0.014
Chezy's Curve (Calc Slope)	33	0.267	0.145	0.024
Dingman and Sharma's Curve (Obs Slope)	33	0.241	0.131	0.023
Dingman and Sharma's Curve (Calc Slope)	33	0.302	0.164	0.029

Table A4-5. P-values of the statistical analyses (post-hoc ANOVA) for observed and modeled rating curves at Site 4, West Run Watershed, Morgantown, WV, U.S.A.

	Observed Curve	Rating Equation Curve	Manning's Curve (Obs Slope)	Manning's Curve (Calc Slope)	Chezy's Curve (Obs Slope)	Chezy's Curve (Calc Slope)	Dingman and Sharma's Curve (Obs Slope)	Dingman and Sharma's Curve (Calc Slope)
Observed Curve	-	1	1	0.002*	1	0.002*	0.03*	<0.05*
Rating Equation Curve	-	-	1	0.002*	1	0.002*	0.03*	<0.05*
Manning's Curve (Obs Slope)	-	-	-	0.007*	1	0.007*	0.08	<0.05*
Manning's Curve (Calc Slope)	-	-	-	-	0.007*	1	1	0.96
Chezy's Curve (Obs Slope)	-	-	-	-	-	0.007*	0.08	<0.05*
Chezy's Curve (Calc Slope)	-	-	-	-	-	-	1	0.96
Dingman and Sharma's Curve (Obs Slope)	-	-	-	-	-	-	-	0.57
Dingman and Sharma's Curve (Calc Slope)	-	-	-	-	-	-	-	-

*= indicates that the difference of the means is significant at the 0.05 level.

Figure A4-2. Box and whisker plots for the results of the statistical analyses (post-hoc ANOVA) of observed and modeled rating curves at Site 4, West Run Watershed, Morgantown, WV, U.S.A.

Figure A4-3. Cross-sectional profile of WRW Site 4, West Run Watershed, Morgantown, WV, USA (Figure 2). Channel Width of zero (0) represents the left bank facing downstream.

Figure A4-5. Photographs showing channel characteristics at Site #4, West Run Watershed, Morgantown, WV, U.S.A. Photo 1 was taken looking upstream in the channel. Photo 2 was taken from the right bank looking downstream.

APPENDIX 5: Site 5

Table A5-1. Streamflow measurements and stage collected at Site 5, West Run Watershed, Morgantown, WV, U.S.A. (Figure 2).

Date	Mean Depth of Cross-Section (m)	Stage(PT in cm)	Barometric Pressure (in cm)	Pressure Corrected Stage (cm)	Stilling Well Offset (cm)	P-Corrected Stage + Offset (cm)	P-Corrected Stage + Offset (m)	SonTec Discharge (m3/s)	Rating Equation Discharge (m3/s)
3/8/2018	0.0450	87.02	69.81	17.21	6.3	23.51	0.2351	0.0091	0.001354182
3/29/2018	0.0839	99.42	80.06	19.36	6.3	25.66	0.2566	0.0294	0.014230368
4/20/2018	0.0610	117.16	96.82	20.34	6.3	26.64	0.2664	0.0381	0.024630677
10/4/2018	0.0988	103.23	85	18.23	6.3	24.53	0.2453	0.0020	0.005760263
10/18/2018	0.0994	114.85	100.05	14.8	6.3	21.1	0.2110	0.0012	0.003154712
10/18/2018	0.0972	114.68	99.97	14.71	6.3	21.01	0.2101	0.0016	0.003554322
10/18/2018	0.1009	114.54	99.86	14.68	6.3	20.98	0.2098	0.0017	0.003692843
10/30/2018	0.1018	107.1	89.77	17.33	6.3	23.63	0.2363	0.0045	0.001713007
12/17/2018	0.1350	102.82	82.23	20.59	6.3	26.89	0.2689	0.0134	0.027738056
2/12/2019	0.1265	98.08	74.18	23.9	6.3	30.2	0.3020	0.0633	0.086286488
2/12/2019	0.1356	97.85	74.34	23.51	6.3	29.81	0.2981	0.0563	0.077705797
5/5/2021	0.2400	1019.7	991.47	28.2	6.3	34.5	0.3450	0.2167	0.2106848
5/5/2021	0.2270	1021.2	991.98	29.2	6.3	35.5	0.3550	0.2453	0.2474438
5/5/2021	0.2180	1020.5	992.09	28.4	6.3	34.7	0.3470	0.2072	0.217800248
5/5/2021	0.2050	1019.3	992.04	27.3	6.3	33.6	0.3360	0.1994	0.180127712
9/1/2021	0.2460	1018.2	988.08	30.1	6.3	36.4	0.3640	0.2674	0.283052912
9/1/2021	0.2410	1016.7	988.07	28.6	6.3	34.9	0.3490	0.2398	0.225033872
9/1/2021	0.2460	1016.5	988.07	28.4	6.3	34.7	0.3470	0.2451	0.217800248
9/1/2021	0.2510	1016.8	988.06	28.7	6.3	35	0.3500	0.2331	0.228695
9/1/2021	0.2600	1017.2	988.01	29.2	6.3	35.5	0.3550	0.2228	0.2474438
9/1/2021	0.2500	1016.5	988.06	28.4	6.3	34.7	0.3470	0.2023	0.217800248
9/1/2021	0.2400	1015.5	988.10	27.4	6.3	33.7	0.3370	0.1997	0.183404768
9/1/2021	0.2440	1015.6	988.10	27.5	6.3	33.8	0.3380	0.2018	0.186711368
9/1/2021	0.2420	1014.8	988.02	26.8	6.3	33.1	0.3310	0.1704	0.164185592
9/1/2021	0.2380	1015.3	988.16	27.1	6.3	33.4	0.3340	0.1738	0.173662232
9/1/2021	0.2260	1014.2	988.30	25.9	6.3	32.2	0.3220	0.1256	0.137351048

Table A5-2. Modeled streamflow at Site 5, West Run Watershed, Morgantown, WV, U.S.A.

Cross-Section Area (m ²)	A (Cross Section area of flow)	P (Wetted Perimeter)	RH=A/P Hydraulic Radius (m)	Observed Slope (m)	Calculated Slope using ArcGIS (m)	Roughness Coefficient (n)	Manning Discharge (m ³ /s) (Obs Slope)	Manning Discharge (m ³ /s) (Calc Slope)	Chezy Coefficient (C)	Chezy Discharge (m ³ /s) (Obs Slope)	Chezy Discharge (m ³ /s) (Calc Slope)	Dingman & Sharma Discharge (m ³ /s) (Obs. Slope)	Dingman & Sharma Discharge (m ³ /s) (Calc Slope)
8.29	0.253	1.9972	0.126512	0.05	0.078	0.2	0.07119236	0.08891923	3.542624095	0.07119236	0.08891923	0.110249622	0.116852715
8.29	0.287	2.0647	0.138994	0.05	0.078	0.2	0.086094199	0.107531621	3.598619718	0.086094199	0.107531621	0.132918848	0.140879652
8.29	0.093	1.646	0.056501	0.05	0.078	0.2	0.015309936	0.019122104	3.097268512	0.015309936	0.019122104	0.024727262	0.026208232
8.29	0.171	1.9412	0.08809	0.05	0.078	0.2	0.037850214	0.047274902	3.335218637	0.037850214	0.047274902	0.06033913	0.063952974
8.29	0.151	1.7224	0.087668	0.05	0.078	0.2	0.033316592	0.04161241	3.332553724	0.033316592	0.04161241	0.052047684	0.055164935
8.29	0.159	1.723	0.092281	0.05	0.078	0.2	0.036301678	0.045340781	3.361155813	0.036301678	0.045340781	0.056442708	0.059823186
8.29	0.163	1.7232	0.094591	0.05	0.078	0.2	0.037833561	0.047254103	3.375037926	0.037833561	0.047254103	0.058689594	0.062204643
8.29	0.171	1.8796	0.090977	0.05	0.078	0.2	0.038672736	0.048302232	3.353192221	0.038672736	0.048302232	0.061122482	0.064783243
8.29	0.247	2.0988	0.117686	0.05	0.078	0.2	0.066318683	0.082832008	3.500184903	0.066318683	0.082832008	0.104291319	0.110537557
8.29	0.405	3.4532	0.117283	0.05	0.078	0.2	0.108492294	0.135506831	3.49818054	0.108492294	0.135506831	0.186021154	0.197162372
8.29	0.388	3.448	0.112529	0.05	0.078	0.2	0.101110528	0.126287009	3.474140801	0.101110528	0.126287009	0.173992159	0.184412934
8.29	0.493	2.5364	0.19437	0.05	0.078	0.2	0.184950159	0.231002675	3.805469102	0.184950159	0.231002675	0.286738086	0.303911464
8.29	0.472	2.5158	0.187614	0.05	0.078	0.2	0.172944835	0.216008029	3.783098525	0.172944835	0.216008029	0.268636237	0.284725455
8.29	0.448	2.493	0.179703	0.05	0.078	0.2	0.159503485	0.199219789	3.756032086	0.159503485	0.199219789	0.248368023	0.263243333
8.29	0.421	2.4666	0.17068	0.05	0.078	0.2	0.144830273	0.180892953	3.723921914	0.144830273	0.180892953	0.226193709	0.23974095
8.29	0.48774	2.473	0.197226	0.05	0.078	0.2	0.184764934	0.230771329	3.81473213	0.184764934	0.230771329	0.284809809	0.301867697
8.29	0.47787	2.463	0.194019	0.05	0.078	0.2	0.179058528	0.22364403	3.804324582	0.179058528	0.22364403	0.27624395	0.29278881
8.29	0.48658	2.473	0.196757	0.05	0.078	0.2	0.184033133	0.229857309	3.813218523	0.184033133	0.229857309	0.283745035	0.300739153
8.29	0.48861	2.445	0.19984	0.05	0.078	0.2	0.186726669	0.233221535	3.823114035	0.186726669	0.233221535	0.286913187	0.304097052
8.29	0.48513	2.396	0.202475	0.05	0.078	0.2	0.187022568	0.233591113	3.831468188	0.187022568	0.233591113	0.28601209	0.303141987
8.29	0.46626	2.376	0.196237	0.05	0.078	0.2	0.176037144	0.219870323	3.81153833	0.176037144	0.219870323	0.269611117	0.285758723
8.29	0.44826	2.347	0.190993	0.05	0.078	0.2	0.16621221	0.207598984	3.794368334	0.16621221	0.207598984	0.254668781	0.269921457
8.29	0.44564	2.317	0.192335	0.05	0.078	0.2	0.166013954	0.207351362	3.79879939	0.166013954	0.207351362	0.253633115	0.268823763
8.29	0.44332	2.313	0.191665	0.05	0.078	0.2	0.164765694	0.205792286	3.796589302	0.164765694	0.205792286	0.251733129	0.266809983
8.29	0.43519	2.305	0.188803	0.05	0.078	0.2	0.160129949	0.200002242	3.787081638	0.160129949	0.200002242	0.244848713	0.259513244
8.29	0.41255	2.281	0.180864	0.05	0.078	0.2	0.147513738	0.1842446	3.760063869	0.147513738	0.1842446	0.226057458	0.239596539

Figure A5-1. Observed and modeled rating curves and streamflow from Site 5, West Run Watershed, Morgantown, West Virginia, U.S.A

Table A5-3. Polynomial rating equations and R^2 values for observed and modeled rating curves at Site 5, West Run Watershed, Morgantown, WV, U.S.A.

	R² Value	Polynomial Equation
Observed Curve	0.98	$y = 14.772x^2 - 6.6645x + 0.7517$
Manning's Curve (Obs Slope)	0.93	$y = 5.1071x^2 - 1.8233x + 0.192$
Manning's Curve (Calc Slope)	0.93	$y = 6.3787x^2 - 2.2774x + 0.2398$
Chezy's Curve (Obs Slope)	0.93	$y = 5.1071x^2 - 1.8233x + 0.192$
Chezy's Curve (Calc Slope)	0.93	$y = 6.3787x^2 - 2.2774x + 0.2398$
Dingman and Sharma's Curve (Obs Slope)	0.93	$y = 6.6269x^2 - 2.1068x + 0.202$
Dingman and Sharma's Curve (Calc Slope)	0.93	$y = 7.0238x^2 - 2.2329x + 0.2141$

Table A5-4. Descriptive statistics for observed and modeled streamflow used to generate the rating curves for Site 5, West Run Watershed, Morgantown, WV, U.S.A.

	Sample Size	Mean (m³/s)	St. Dev.	SE of Mean
Observed	26	0.13	0.1	0.02
Manning's Curve (Obs Slope)	26	0.123	0.06	0.012
Manning's Curve (Calc Slope)	26	0.154	0.08	0.015
Chezy's Curve (Obs Slope)	26	0.123	0.06	0.012
Chezy's Curve (Calc Slope)	26	0.154	0.08	0.015
Dingman and Sharma's Curve (Obs Slope)	26	0.191	0.094	0.018
Dingman and Sharma's Curve (Calc Slope)	26	0.202	0.1	0.019

Table A5-5. P-values of the statistical analyses (post-hoc ANOVA) for observed and modeled rating curves at Site 5, West Run Watershed, Morgantown, WV, U.S.A.

	Observed Curve	Rating Equation Curve	Manning's Curve (Obs Slope)	Manning's Curve (Calc Slope)	Chezy's Curve (Obs Slope)	Chezy's Curve (Calc Slope)	Dingman and Sharma's Curve (Obs Slope)	Dingman and Sharma's Curve (Calc Slope)
Observed Curve	-	1	1	0.97	1	0.97	0.16	0.05*
Rating Equation Curve	-	-	1	0.97	1	0.97	0.16	0.05*
Manning's Curve (Obs Slope)	-	-	-	0.90	1	0.90	0.08	0.02*
Manning's Curve (Calc Slope)	-	-	-	-	0.90	1	0.75	0.43
Chezy's Curve (Obs Slope)	-	-	-	-	-	0.90	0.07	0.02*
Chezy's Curve (Calc Slope)	-	-	-	-	-	-	0.75	0.43
Dingman and Sharma's Curve (Obs Slope)	-	-	-	-	-	-	-	1
Dingman and Sharma's Curve (Calc Slope)	-	-	-	-	-	-	-	-

*= indicates that the difference of the means is significant at the 0.05 level.

Figure A5-2. Box and whisker plots for the results of the statistical analyses (post-hoc ANOVA) of observed and modeled rating curves at Site 5, West Run Watershed, Morgantown, WV, U.S.A.

Figure A5-3. Cross-sectional profile of WRW Site 5, West Run Watershed, Morgantown, WV, USA (Figure 2). Channel Width of zero (0) represents the left bank facing downstream.

Figure A5-4. Plan view profile of WRW Site 5, West Run Watershed, Morgantown, WV, U.S.A. (Figure 2). Showing the positioning of stilling well in relation to where the streamflow was measured. Along with the channel width at the stilling well, point where cross-sections were performed, and 6.0m upstream and downstream from the stilling well.

Figure A5-5. Photographs showing channel characteristics at Site #5, West Run Watershed, Morgantown, WV, U.S.A. Photo 1 was taken looking upstream in the channel. Photo 2 was taken from the right bank looking downstream.

APPENDIX 6: Site 6

Table A6-1. Streamflow measurements and stage collected at Site 6, West Run Watershed, Morgantown, WV, U.S.A. (Figure 2).

Date	Mean Depth of Cross-Section (m)	Stage(PT in cm)	Barometric Pressure (in cm)	Pressure Corrected Stage (cm)	Stilling Well Offset (cm)	P-Corrected Stage + Offset (cm)	P-Corrected Stage + Offset (m)	SonTec Discharge (m3/s)	Rating Equation Discharge (m3/s)
12/5/2017	0.0964	99.42	80.07	19.35	7.7	27.05	0.2705	0.0587	0.06433941
1/3/2017	0.0910	103.08	86.88	16.2	7.7	23.9	0.2390	0.0159	0.020736792
1/12/2018	0.1272	96.16	70.27	25.89	7.7	33.59	0.3359	0.2359	0.20617194
2/9/2018	0.0921	113.36	92.05	21.31	7.7	29.01	0.2901	0.1293	0.099578357
2/14/2018	0.0616	107.52	87.67	19.85	7.7	27.55	0.2755	0.0921	0.072737944
3/8/2018	0.0852	95.03	77.68	17.35	7.7	25.05	0.2505	0.0636	0.034793174
3/29/2018	0.0982	105.28	80.58	24.7	7.7	32.4	0.3240	0.1775	0.175210301
4/4/2018	0.2122	111.39	78.3	33.09	7.7	40.79	0.4079	0.5024	0.442407975
4/20/2018	0.0939	118.06	96.62	21.44	7.7	29.14	0.2914	0.1449	0.102135597
6/18/2018	0.1222	104.31	87.25	17.06	7.7	24.76	0.2476	0.0261	0.031046612
6/18/2018	0.1146	104.28	87.24	17.04	7.7	24.74	0.2474	0.0268	0.030793248
7/18/2018	0.1038	101.26	86.44	14.82	7.7	22.52	0.2252	0.0066	0.006695701
7/18/2018	0.0866	101.19	86.4	14.79	7.7	22.49	0.2249	0.0067	0.006424705
7/23/2018	0.1052	95.9	81.2	14.7	7.7	22.4	0.2240	0.0100	0.005620461
7/23/2018	0.1030	95.98	81.27	14.71	7.7	22.41	0.2241	0.0112	0.005709174
7/26/2018	0.0978	100.09	83.97	16.12	7.7	23.82	0.2382	0.0228	0.019838619
7/26/2018	0.1012	100.13	84	16.13	7.7	23.83	0.2383	0.0244	0.019950324
9/11/2018	0.1466	111.39	89.91	21.48	7.7	29.18	0.2918	0.0966	0.102927946
9/18/2018	0.1500	106.64	81.32	25.32	7.7	33.02	0.3302	0.1730	0.191055469
9/25/2018	0.2076	121.08	88.97	32.11	7.7	39.81	0.3981	0.3937	0.40531875
10/16/2018	0.1070	107.07	89.16	17.91	7.7	25.61	0.2561	0.0458	0.042413275
10/16/2018	0.1106	106.87	89.04	17.83	7.7	25.53	0.2553	0.0478	0.041293601
12/17/2018	0.1494	105.93	82.27	23.66	9.5	33.185	0.3319	0.1446	0.19537719
1/24/2019	0.3652	114.83	67.8	47.03	9.5	56.555	0.5656	1.2213	1.252769414
1/24/2019	0.3703	115.47	69.13	46.34	9.5	55.865	0.5587	1.2707	1.208880595
2/26/2019	0.1442	116.8	94.57	22.23	9.5	31.755	0.3176	0.1044	0.159386771
2/26/2019	0.1402	116.71	94.6	22.11	9.5	31.635	0.3164	0.1064	0.156517177
3/28/2019	0.1186	107.93	90.93	17	9.5	26.525	0.2653	0.0314	0.055956604
12/17/2019	0.3322	118.15	75.25	42.9	9.5	52.4	0.5240	0.9296	1.000137981
4/9/2020	0.2344	1009.9	983.27	26.6	9.5	36.1	0.3610	0.3258	0.278996152
10/7/2021	0.1890	1030.70	1005.66	25.04	9.5	34.54	0.3454	0.2364	0.232535091
10/7/2021	0.1820	1029.90	1005.60	24.3	9.5	33.8	0.3380	0.1982	0.211873775
10/7/2021	0.1680	1028.70	1005.47	23.23	9.5	32.73	0.3273	0.1705	0.183566543
10/7/2021	0.1610	1027.80	1005.40	22.4	9.5	31.9	0.3190	0.1216	0.162885304
10/16/2021	0.2640	1024.80	991.54	33.26	9.5	42.76	0.4276	0.5545	0.521669761
10/16/2021	0.2510	1024.20	991.47	32.73	9.5	42.23	0.4223	0.5200	0.499727652

Table A6-2. Modeled streamflow at Site 6, West Run Watershed, Morgantown, WV, U.S.A.

Cross-Section Area (m ²)	A (Cross Section area of flow)	P (Wetted Perimeter)	RH=A/P Hydraulic Radius (m)	Observed Slope (m)	Calculated Slope using ArcGIS (m)	Roughness Coefficient (n)	Manning Discharge (m ³ /s) (Obs Slope)	Manning Discharge (m ³ /s) (Calc Slope)	Chezy Coefficient (C)	Chezy Discharge (m ³ /s) (Obs Slope)	Chezy Discharge (m ³ /s) (Calc Slope)	Dingman & Sharma Discharge (m ³ /s) (Obs. Slope)	Dingman & Sharma Discharge (m ³ /s) (Calc Slope)
3.69	0.309	2.1062	0.146786	0.02	0.016	0.072	0.168976961	0.151137589	10.08745378	0.168976961	0.151137589	0.12769239	0.122398013
3.69	0.259	2.0098	0.128819	0.02	0.016	0.072	0.129706524	0.116013042	9.870312755	0.129706524	0.116013042	0.098421154	0.09434042
3.69	0.414	2.2792	0.181434	0.02	0.016	0.072	0.260315977	0.232833688	10.4501021	0.260315977	0.232833688	0.195500961	0.187395108
3.69	0.340	2.1619	0.157471	0.02	0.016	0.072	0.194995786	0.174409533	10.20628133	0.194995786	0.174409533	0.147050292	0.140953299
3.69	0.317	2.1207	0.149543	0.02	0.016	0.072	0.175501674	0.156973469	10.1187868	0.175501674	0.156973469	0.132549537	0.127053774
3.69	0.277	2.0460	0.135509	0.02	0.016	0.072	0.143669159	0.128501602	9.9539556	0.143669159	0.128501602	0.108835855	0.104323307
3.69	0.395	2.2505	0.175313	0.02	0.016	0.072	0.242743861	0.21711671	10.39049894	0.242743861	0.21711671	0.182489955	0.174923563
3.69	0.528	2.4271	0.217716	0.02	0.016	0.072	0.375630519	0.33597415	10.77248462	0.375630519	0.33597415	0.280360735	0.268736429
3.69	0.429	4.7598	0.09013	0.02	0.016	0.072	0.169389123	0.151506237	9.29991405	0.169389123	0.151506237	0.154283573	0.147886673
3.69	0.224	2.0734	0.108035	0.02	0.016	0.072	0.099802281	0.089265874	9.585063424	0.099802281	0.089265874	0.077404595	0.074195249
3.69	0.244	2.3632	0.103325	0.02	0.016	0.072	0.105478811	0.094343117	9.512961263	0.105478811	0.094343117	0.084035706	0.080551421
3.69	0.229	2.4176	0.094722	0.02	0.016	0.072	0.093465645	0.083598214	9.377261117	0.093465645	0.083598214	0.07536458	0.072239817
3.69	0.198	2.4592	0.080514	0.02	0.016	0.072	0.072515123	0.064859497	9.126677969	0.072515123	0.064859497	0.059543815	0.057075011
3.69	0.241	2.4966	0.096531	0.02	0.016	0.072	0.099611985	0.089095668	9.406878102	0.099611985	0.089095668	0.080625621	0.077282724
3.69	0.235	2.4918	0.094309	0.02	0.016	0.072	0.095635724	0.085539192	9.370439271	0.095635724	0.085539192	0.07755045	0.074335057
3.69	0.253	2.7864	0.090798	0.02	0.016	0.072	0.10038937	0.089790982	9.311372056	0.10038937	0.089790982	0.083289651	0.079836299
3.69	0.262	2.7932	0.093799	0.02	0.016	0.072	0.106238835	0.095022902	9.361972905	0.106238835	0.095022902	0.087911758	0.084266765
3.69	0.436	3.2652	0.133529	0.02	0.016	0.072	0.223727889	0.200108307	9.929566464	0.223727889	0.200108307	0.184012863	0.176383328
3.69	0.548	3.9578	0.138461	0.02	0.016	0.072	0.288080726	0.257667234	9.989765398	0.288080726	0.257667234	0.244129426	0.234007341
3.69	0.791	4.2252	0.18721	0.02	0.016	0.072	0.508446341	0.454768233	10.50483025	0.508446341	0.454768233	0.423635698	0.406070931
3.69	0.286	2.8812	0.099264	0.02	0.016	0.072	0.120432477	0.107718082	9.450749995	0.120432477	0.107718082	0.099663069	0.095530843
3.69	0.287	2.8124	0.102048	0.02	0.016	0.072	0.123102707	0.110106408	9.494417056	0.123102707	0.110106408	0.101185256	0.096989917
3.69	0.547	3.957	0.138236	0.02	0.016	0.072	0.28724381	0.256918674	9.987061316	0.28724381	0.256918674	0.243448719	0.233354857
3.69	1.524	4.8556	0.313864	0.02	0.016	0.072	1.382490571	1.236537158	11.44962284	1.382490571	1.236537158	1.124185659	1.077574717
3.69	1.519	4.86	0.312551	0.02	0.016	0.072	1.374109298	1.22904072	11.44162618	1.374109298	1.22904072	1.117984338	1.071630515
3.69	0.451	3.4124	0.132165	0.02	0.016	0.072	0.229845911	0.205580433	9.912585318	0.229845911	0.205580433	0.190675799	0.182770007
3.69	0.438	3.4046	0.128649	0.02	0.016	0.072	0.219244457	0.196098204	9.868144634	0.219244457	0.196098204	0.182268738	0.174711519
3.69	0.316	2.9044	0.1088	0.02	0.016	0.072	0.141456645	0.12652267	9.596347055	0.141456645	0.12652267	0.116221121	0.111402365
3.69	1.392	4.8354	0.287877	0.02	0.016	0.072	1.192045839	1.066198211	11.28587689	1.192045839	1.066198211	0.976498102	0.936010576
3.69	0.804	3.8978	0.20627	0.02	0.016	0.072	0.551310438	0.493107046	10.67595955	0.551310438	0.493107046	0.448889858	0.430278004
3.69	0.75019	4.34	0.172855	0.02	0.016	0.072	0.457237105	0.408965299	10.36607692	0.457237105	0.408965299	0.385610069	0.36962192
3.69	0.72174	4.326	0.166838	0.02	0.016	0.072	0.429628203	0.384271147	10.30504471	0.429628203	0.384271147	0.363327443	0.348263175
3.69	0.65177	4.222	0.154375	0.02	0.016	0.072	0.36840679	0.329513051	10.17255843	0.36840679	0.329513051	0.312509336	0.299552086
3.69	0.61287	4.132	0.148323	0.02	0.016	0.072	0.337305093	0.301694846	10.10498125	0.337305093	0.301694846	0.286131821	0.274268235
3.69	1.07709	4.605	0.233896	0.02	0.016	0.072	0.803124241	0.718336159	10.90195948	0.803124241	0.718336159	0.665181836	0.637602092
3.69	1.02484	4.579	0.223813	0.02	0.016	0.072	0.742042623	0.663703099	10.822188	0.742042623	0.663703099	0.616529109	0.590966603

Figure A6-1. Observed and modeled rating curves and streamflow from Site 6, West Run Watershed, Morgantown, West Virginia, U.S.A

Table A6-3. Polynomial rating equations and R^2 values for observed and modeled rating curves at Site 6, West Run Watershed, Morgantown, WV, U.S.A.

	R² Value	Polynomial Equation
Observed Curve	0.99	$y = 8.0958x^2 - 2.7406x + 0.2133$
Manning's Curve (Obs Slope)	0.97	$y = 6.926x^2 - 1.5484x + 0.0768$
Manning's Curve (Calc Slope)	0.97	$y = 6.1948x^2 - 1.3849x + 0.0687$
Chezy's Curve (Obs Slope)	0.97	$y = 6.926x^2 - 1.5484x + 0.0768$
Chezy's Curve (Calc Slope)	0.97	$y = 6.1948x^2 - 1.3849x + 0.0687$
Dingman and Sharma's Curve (Obs Slope)	0.96	$y = 5.4636x^2 - 1.1135x + 0.0356$
Dingman and Sharma's Curve (Calc Slope)	0.96	$y = 5.237x^2 - 1.0673x + 0.0341$

Table A6-4. Descriptive statistics for observed and modeled streamflow used to generate the rating curves for Site 6, West Run Watershed, Morgantown, WV, U.S.A.

	Sample Size	Mean (m³/s)	St. Dev.	SE of Mean
Observed	36	0.229	0.318	0.053
Manning's Curve (Obs Slope)	36	0.357	0.357	0.059
Manning's Curve (Calc Slope)	36	0.319	0.319	0.053
Chezy's Curve (Obs Slope)	36	0.357	0.357	0.059
Chezy's Curve (Calc Slope)	36	0.319	0.319	0.053
Dingman and Sharma's Curve (Obs Slope)	36	0.282	0.285	0.047
Dingman and Sharma's Curve (Calc Slope)	36	0.27	0.273	0.045

Table A6-5. P-values of the statistical analyses (post-hoc ANOVA) for observed and modeled rating curves at Site 6, West Run Watershed, Morgantown, WV, U.S.A.

	Observed Curve	Rating Equation Curve	Manning's Curve (Obs Slope)	Manning's Curve (Calc Slope)	Chezy's Curve (Obs Slope)	Chezy's Curve (Calc Slope)	Dingman and Sharma's Curve (Obs Slope)	Dingman and Sharma's Curve (Calc Slope)
Observed Curve	-	1	0.71	0.94	0.71	0.94	1	1
Rating Equation Curve	-	-	0.71	0.94	0.71	0.94	1	1
Manning's Curve (Obs Slope)	-	-	-	1	1	1	0.98	0.95
Manning's Curve (Calc Slope)	-	-	-	-	1	1	1	1
Chezy's Curve (Obs Slope)	-	-	-	-	-	1	0.98	0.95
Chezy's Curve (Calc Slope)	-	-	-	-	-	-	1	1
Dingman and Sharma's Curve (Obs Slope)	-	-	-	-	-	-	-	1
Dingman and Sharma's Curve (Calc Slope)	-	-	-	-	-	-	-	-

Figure A6-2. Box and whisker plots for the results of the statistical analyses (post-hoc ANOVA) of observed and modeled rating curves at Site 6, West Run Watershed, Morgantown, WV, U.S.A.

Figure A6-3. Cross-sectional profile of WRW Site 6, West Run Watershed, Morgantown, WV, USA (Figure 2). Channel Width of zero (0) represents the left bank facing downstream.

Figure A6-4. Plan view profile of WRW Site 6, West Run Watershed, Morgantown, WV, U.S.A. (Figure 2). Showing the positioning of stilling well in relation to where the streamflow was measured. Along with the channel width at the stilling well, point where cross-sections were performed, and 6.0m upstream and downstream from the stilling well.

Figure A6-5. Photographs showing channel characteristics at Site #6, West Run Watershed, Morgantown, WV, U.S.A. Photo 1 was taken looking upstream in the channel. Photo 2 was taken from the right bank looking downstream.

APPENDIX 7: Site 7

Table A7-1. Streamflow measurements and stage collected at Site 7, West Run Watershed, Morgantown, WV, U.S.A. (Figure 2).

Stage(PT in cm)	Barometric Pressure (in cm)	Pressure Corrected Stage (cm)	Stilling Well Offset (cm)	P-Corrected Stage + Offset (cm)	P-Corrected Stage + Offset (m)	SonTec Discharge (m3/s)	Rating Equation Discharge (m3/s)
102.12	87.26	14.86	7.6	22.46	0.2246	0.1079	0.115517447
92.19	89.6	2.59	7.6	10.19	0.1019	0.0039	0.005000171
92.14	89.41	2.73	7.6	10.33	0.1033	0.0043	0.005520038
86.56	82.04	4.52	7.6	12.12	0.1212	0.0092	0.013674614
86.47	82.08	4.39	7.6	11.99	0.1199	0.0092	0.012988203
89.55	70.81	18.74	7.6	26.34	0.2634	0.1731	0.177811996
88.76	78.73	10.03	7.6	17.63	0.1763	0.0535	0.056330251
89.8	78.77	11.03	7.6	18.63	0.1863	0.0600	0.066912841
99.96	95.29	4.67	7.6	12.27	0.1227	0.0184	0.014484957
86.25	82.72	3.53	7.6	11.13	0.1113	0.0060	0.008818897
72.03	66.65	5.38	7.6	12.98	0.1298	0.0148	0.018587056
70.89	66.94	3.95	7.6	11.55	0.1155	0.0134	0.010774419
101.02	91.14	9.88	7.6	17.48	0.1748	0.0519	0.054818146
99.57	91.26	8.31	7.6	15.91	0.1591	0.0474	0.040169945
77.99	74.13	3.86	7.6	11.46	0.1146	0.0100	0.010342417
85.39	82.36	3.03	7.6	10.63	0.1063	0.0120	0.006691647
90.01	75.25	14.76	7.6	22.36	0.2236	0.1170	0.114085613
1006.12	990.18	16	7.6	23.6	0.236	0.1441	0.132457283
1018.7	1003.36	15.3	7.6	22.9	0.229	0.1264	0.121921212
1013.1	1002.25	10.9	7.6	18.5	0.185	0.0559	0.065487745
1000.70	992.57	8.13	7.6	15.73	0.1573	0.0486	0.038628006
1000.50	992.38	8.12	7.6	15.72	0.1572	0.0345	0.038543172
1000.40	992.55	7.85	7.6	15.45	0.1545	0.0449	0.036285645

Table A7-2. Modeled streamflow at Site 7, West Run Watershed, Morgantown, WV, U.S.A.

Cross-Section Area (m ²)	A (Cross Section area of flow)	P (Wetted Perimeter)	RH=A/P Hydraulic Radius (m)	Observed Slope (m)	Calculated Slope using ArcGIS (m)	Roughness Coefficient (n)	Manning Discharge (m ³ /s) (Obs Slope)	Manning Discharge (m ³ /s) (Calc Slope)	Chezy Coefficient (C)	Chezy Discharge (m ³ /s) (Obs Slope)	Chezy Discharge (m ³ /s) (Calc Slope)	Dingman & Sharma Discharge (m ³ /s) (Obs. Slope)	Dingman & Sharma Discharge (m ³ /s) (Calc Slope)
4.53	0.252	1.7394	0.144878	0.02	0.044	0.105	0.093625386	0.13886889	6.90204119	0.093625386	0.13886889	0.099940867	0.113908474
4.53	0.05	0.893	0.055991	0.02	0.044	0.105	0.009856167	0.014619059	5.890657765	0.009856167	0.014619059	0.010247999	0.011680246
4.53	0.051	0.9	0.056667	0.02	0.044	0.105	0.010134002	0.015031154	5.902445405	0.010134002	0.015031154	0.010539275	0.012012223
4.53	0.063	0.9266	0.067991	0.02	0.044	0.105	0.014135085	0.020965719	6.084413807	0.014135085	0.020965719	0.014524648	0.016554594
4.53	0.062	0.9265	0.066919	0.02	0.044	0.105	0.013764113	0.020415479	6.068319128	0.013764113	0.020415479	0.014164257	0.016143836
4.53	0.348	2.01	0.173134	0.02	0.044	0.105	0.145599673	0.215959215	7.110081278	0.145599673	0.215959215	0.156720416	0.178623459
4.53	0.153	1.5308	0.099948	0.02	0.044	0.105	0.044381208	0.065827969	6.487930622	0.044381208	0.065827969	0.047979099	0.054684596
4.53	0.165	1.612	0.102357	0.02	0.044	0.105	0.048628281	0.072127396	6.513741489	0.048628281	0.072127396	0.052924416	0.060321065
4.53	0.075	1.2812	0.058539	0.02	0.044	0.105	0.015229414	0.022588871	5.934508504	0.015229414	0.022588871	0.01678512	0.019130986
4.53	0.07	1.265	0.055336	0.02	0.044	0.105	0.013690798	0.020306734	5.879114972	0.013690798	0.020306734	0.015135712	0.01725106
4.53	0.132	1.4984	0.088094	0.02	0.044	0.105	0.035199007	0.052208564	6.352846991	0.035199007	0.052208564	0.038362909	0.04372446
4.53	0.128	1.49	0.085906	0.02	0.044	0.105	0.033564857	0.049784728	6.326273804	0.033564857	0.049784728	0.036632506	0.041752217
4.53	0.158	1.6662	0.094827	0.02	0.044	0.105	0.044252325	0.065636805	6.431303829	0.044252325	0.065636805	0.048786155	0.055604445
4.53	0.14	1.5498	0.090334	0.02	0.044	0.105	0.037962545	0.056307554	6.379492004	0.037962545	0.056307554	0.041519201	0.047321871
4.53	0.092	1.437	0.064022	0.02	0.044	0.105	0.019830526	0.029413423	6.023735272	0.019830526	0.029413423	0.022108302	0.02519813
4.53	0.1	1.3838	0.072265	0.02	0.044	0.105	0.023367387	0.034659436	6.146555582	0.023367387	0.034659436	0.025590014	0.029166441
4.53	0.203	1.5524	0.130765	0.02	0.044	0.105	0.070439566	0.104478761	6.785149716	0.070439566	0.104478761	0.074437137	0.084840375
4.53	0.273	1.941	0.140649	0.02	0.044	0.105	0.099444268	0.147499685	6.868051655	0.099444268	0.147499685	0.108485946	0.123647801
4.53	0.16723	1.381	0.121093	0.02	0.044	0.105	0.055129861	0.081770798	6.698806804	0.055129861	0.081770798	0.057503675	0.065540314
4.53	0.1141	1.136	0.10044	0.02	0.044	0.105	0.033205974	0.049252418	6.493246944	0.033205974	0.049252418	0.034076802	0.038839332
4.53	0.08129	0.976	0.083289	0.02	0.044	0.105	0.020881147	0.030971747	6.293736919	0.020881147	0.030971747	0.021242632	0.024211474
4.53	0.07926	0.998	0.079419	0.02	0.044	0.105	0.019724021	0.029255451	6.244024839	0.019724021	0.029255451	0.020232972	0.023060706
4.53	0.07606	0.99	0.076828	0.02	0.044	0.105	0.018513823	0.027460437	6.20960853	0.018513823	0.027460437	0.019024124	0.021682911

Figure A7-1. Observed and modeled rating curves and streamflow from Site 7, West Run Watershed, Morgantown, West Virginia, U.S.A

Table A7-3. Polynomial rating equations and R^2 values for observed and modeled rating curves at Site 7, West Run Watershed, Morgantown, WV, U.S.A.

	R² Value	Polynomial Equation
Observed Curve	0.99	$y = 4.3642x^2 - 0.5242x + 0.0131$
Manning's Curve (Obs Slope)	0.90	$y = 5.5033x^2 - 1.2968x + 0.0942$
Manning's Curve (Calc Slope)	0.90	$y = 8.1627x^2 - 1.9235x + 0.1397$
Chezy's Curve (Obs Slope)	0.90	$y = 5.5033x^2 - 1.2968x + 0.0942$
Chezy's Curve (Calc Slope)	0.90	$y = 8.1627x^2 - 1.9235x + 0.1397$
Dingman and Sharma's Curve (Obs Slope)	0.89	$y = 5.9797x^2 - 1.419x + 0.1033$
Dingman and Sharma's Curve (Calc Slope)	0.89	$y = 6.8154x^2 - 1.6173x + 0.1178$

Table A7-4. Descriptive statistics for observed and modeled streamflow used to generate the rating curves for Site 7, West Run Watershed, Morgantown, WV, U.S.A.

	Sample Size	Mean (m³/s)	St. Dev.	SE of Mean
Observed	23	0.051	0.05	0.01
Manning's Curve (Obs Slope)	23	0.04	0.034	0.01
Manning's Curve (Calc Slope)	23	0.059	0.05	0.01
Chezy's Curve (Obs Slope)	23	0.04	0.034	0.01
Chezy's Curve (Calc Slope)	23	0.059	0.05	0.01
Dingman and Sharma's Curve (Obs Slope)	23	0.043	0.037	0.01
Dingman and Sharma's Curve (Calc Slope)	23	0.049	0.042	0.01

Table A7-5. P-values of the statistical analyses (post-hoc ANOVA) for observed and modeled rating curves at Site 7, West Run Watershed, Morgantown, WV, U.S.A.

	Observed Curve	Rating Equation Curve	Manning's Curve (Obs Slope)	Manning's Curve (Calc Slope)	Chezy's Curve (Obs Slope)	Chezy's Curve (Calc Slope)	Dingman and Sharma's Curve (Obs Slope)	Dingman and Sharma's Curve (Calc Slope)
Observed Curve	-	1	0.99	1	0.99	1	1	1
Rating Equation Curve	-	-	0.99	1	0.99	1	1	0.99
Manning's Curve (Obs Slope)	-	-	-	0.81	1	0.81	1	1
Manning's Curve (Calc Slope)	-	-	-	-	0.81	1	0.91	0.99
Chezy's Curve (Obs Slope)	-	-	-	-	-	0.81	1	1
Chezy's Curve (Calc Slope)	-	-	-	-	-	-	0.91	0.99
Dingman and Sharma's Curve (Obs Slope)	-	-	-	-	-	-	-	1
Dingman and Sharma's Curve (Calc Slope)	-	-	-	-	-	-	-	-

Figure A7-2. Box and whisker plots for the results of the statistical analyses (post-hoc ANOVA) of observed and modeled rating curves at Site 7, West Run Watershed, Morgantown, WV, U.S.A.

Figure A7-3. Cross-sectional profile of WRW Site 7, West Run Watershed, Morgantown, WV, USA (Figure 2). Channel Width of zero (0) represents the left bank facing downstream.

Figure A7-4. Plan view profile of WRW Site 7, West Run Watershed, Morgantown, WV, U.S.A. (Figure 2). Showing the positioning of stilling well in relation to where the streamflow was measured. Along with the channel width at the stilling well, point where cross-sections were performed, and 6.0m upstream and downstream from the stilling well.

Figure A7-5. Photographs showing channel characteristics at Site #7, West Run Watershed, Morgantown, WV, U.S.A. Photo 1 was taken looking upstream in the channel. Photo 2 was taken from the left bank looking downstream.

APPENDIX 8: Site 8

Table A8-1. Streamflow measurements and stage collected at Site 8, West Run Watershed, Morgantown, WV, U.S.A. (Figure 2).

Date	Mean Depth of Cross-Section (m)	Stage(PT in cm)	Barometric Pressure (in cm)	Pressure Corrected Stage (cm)	Stilling Well Offset (cm)	P-Corrected Stage + Offset (cm)	P-Corrected Stage + Offset (m)	SonTec Discharge (m3/s)	Rating Equation Discharge (m3/s)
1/2/2018	0.0457	109.18	93.67	15.51	7	22.51	0.2251	0.0084	0.028489316
1/12/2018	0.0654	87.06	70.48	16.58	7	23.58	0.2358	0.0608	0.040200248
3/14/2018	0.0693	92.54	79	13.54	7	20.54	0.2054	0.0212	0.010085902
3/29/2018	0.0612	94.82	78.75	16.07	7	23.07	0.2307	0.0505	0.034467808
9/9/2018	0.1130	112.12	86.75	25.37	7	32.37	0.3237	0.2031	0.182104913
10/18/2018	0.0637	115.59	99.66	15.93	7	22.93	0.2293	0.0172	0.03294218
10/18/2018	0.0652	114.28	99.69	14.59	7	21.59	0.2159	0.0177	0.019385466
10/18/2018	0.0613	114.14	99.54	14.6	7	21.6	0.2160	0.0166	0.019479622
10/30/2018	0.0698	104.47	89.49	14.98	7	21.98	0.2198	0.0218	0.023135716
12/17/2018	0.0872	97.46	82.02	15.44	6.4	21.84	0.2184	0.0198	0.021771017
12/17/2018	0.0899	98.44	81.9	16.54	6.4	22.94	0.2294	0.0202	0.033050468
1/24/2019	0.1710	103.7	70.37	33.33	6.4	39.73	0.3973	0.3401	0.363599635
2/6/2019	0.1561	108.16	78.7	29.46	6.4	35.86	0.3586	0.2546	0.261045212
2/26/2019	0.1039	112.29	95.31	16.98	6.4	23.38	0.2338	0.0558	0.03791954
4/25/2019	0.0936	94.06	79.24	14.82	6.4	21.22	0.2122	0.0165	0.01597581
4/25/2019	0.0875	93.43	79.32	14.11	6.4	20.51	0.2051	0.0180	0.009837284
4/26/2019	0.1235	85.02	67.4	17.62	6.4	24.02	0.2402	0.0362	0.045366289
4/26/2019	0.1210	85.79	67.5	18.29	6.4	24.69	0.2469	0.0374	0.053624908
4/29/2019	0.1015	103.61	89.83	13.78	6.4	20.18	0.2018	0.0151	0.007165132
4/30/2019	0.1225	108.86	91.38	17.48	6.4	23.88	0.2388	0.0498	0.043700403
5/13/2019	0.1106	92.19	74.05	18.14	6.4	24.54	0.2454	0.0328	0.051734835
5/14/2019	0.1030	99.04	82.35	16.69	6.4	23.09	0.2309	0.03449	0.034687442
12/17/2019	0.1490	104.61	75.15	29.46	6.4	35.86	0.3586	0.2862	0.261045212
8/16/2021	0.1330	1034.5	1004.67	29.8	6.4	36.2	0.3620	0.2739	0.269422308
8/16/2021	0.1350	1034.4	1004.72	29.7	6.4	36.1	0.3610	0.2882	0.266945801
8/16/2021	0.1400	1035.5	1004.72	30.8	6.4	37.2	0.3720	0.3273	0.294767394
8/16/2021	0.1400	1036.6	1004.65	31.9	6.4	38.3	0.3830	0.3122	0.323865028
8/16/2021	0.1390	1035.9	1004.68	31.2	6.4	37.6	0.3760	0.3097	0.30520071
8/16/2021	0.1210	1033.6	1004.66	28.9	6.4	35.3	0.3530	0.2239	0.247513396
8/16/2021	0.1140	1032.8	1004.58	28.2	6.4	34.6	0.3460	0.2011	0.231063696

Table A8-2. Modeled streamflow at Site 8, West Run Watershed, Morgantown, WV, U.S.A.

Cross-Section Area (m ²)	A (Cross Section area of flow)	P (Wetted Perimeter)	RH=A/P Hydraulic Radius (m)	Observed Slope (m)	Calculated Slope using ArcGIS (m)	Roughness Coefficient (n)	Manning Discharge (m ³ /s) (Obs Slope)	Manning Discharge (m ³ /s) (Calc Slope)	Chezy Coefficient (C)	Chezy Discharge (m ³ /s) (Obs Slope)	Chezy Discharge (m ³ /s) (Calc Slope)	Dingman & Sharma Discharge (m ³ /s) (Obs. Slope)	Dingman & Sharma Discharge (m ³ /s) (Calc Slope)
1.62	0.237	1.9645	0.120497	0.01	0.03	0.14	0.041249092	0.071445524	5.019972293	0.041249092	0.071445524	0.075057335	0.092611041
1.62	0.254	1.9995	0.126927	0.01	0.03	0.14	0.045784229	0.079300611	5.063659301	0.045784229	0.079300611	0.083158501	0.102606833
1.62	0.205	1.8975	0.108185	0.01	0.03	0.14	0.033290802	0.05766136	4.930600256	0.033290802	0.05766136	0.060824633	0.075049729
1.62	0.246	1.9829	0.123883	0.01	0.03	0.14	0.04360455	0.075525295	5.043212452	0.04360455	0.075525295	0.079265688	0.097803605
1.62	0.302	2.8934	0.104375	0.01	0.03	0.14	0.047820181	0.082826984	4.901229535	0.047820181	0.082826984	0.094302733	0.116357373
1.62	0.078	1.3464	0.057932	0.01	0.03	0.14	0.008341553	0.014447993	4.443160972	0.008341553	0.014447993	0.015227616	0.018788908
1.62	0.077	1.346	0.057207	0.01	0.03	0.14	0.008165695	0.014143398	4.433835489	0.008165695	0.014143398	0.014923429	0.018413581
1.62	0.077	1.346	0.057207	0.01	0.03	0.14	0.008165695	0.014143398	4.433835489	0.008165695	0.014143398	0.014923429	0.018413581
1.62	0.091	1.4348	0.063423	0.01	0.03	0.14	0.010337449	0.017904987	4.510731414	0.010337449	0.017904987	0.018918744	0.023343283
1.62	0.13	3.244	0.040074	0.01	0.03	0.14	0.010874025	0.018834364	4.178454866	0.010874025	0.018834364	0.023924193	0.02951936
1.62	0.134	3.25	0.041231	0.01	0.03	0.14	0.011423286	0.019785712	4.198319994	0.011423286	0.019785712	0.025073748	0.030937761
1.62	0.408	2.998	0.136091	0.01	0.03	0.14	0.077105345	0.133550375	5.122831289	0.077105345	0.133550375	0.149235634	0.184137467
1.62	0.371	2.8327	0.13097	0.01	0.03	0.14	0.068343113	0.118373745	5.090192251	0.068343113	0.118373745	0.131456382	0.16220017
1.62	0.15	1.6558	0.090591	0.01	0.03	0.14	0.021611528	0.037432265	4.78687986	0.021611528	0.037432265	0.039212556	0.048383221
1.62	0.135	1.635	0.082569	0.01	0.03	0.14	0.018284499	0.031669682	4.713475994	0.018284499	0.031669682	0.033392172	0.04120162
1.62	0.136	1.625	0.083692	0.01	0.03	0.14	0.018586655	0.032193031	4.724105141	0.018586655	0.032193031	0.03386508	0.041785128
1.62	0.178	1.695	0.105015	0.01	0.03	0.14	0.028300373	0.049017685	4.906219952	0.028300373	0.049017685	0.050848662	0.062740671
1.62	0.175	1.6902	0.103538	0.01	0.03	0.14	0.027561953	0.047738702	4.894653538	0.027561953	0.047738702	0.049563317	0.061154721
1.62	0.139	1.5748	0.088265	0.01	0.03	0.14	0.019682474	0.034091046	4.76617733	0.019682474	0.034091046	0.035490234	0.043790358
1.62	0.196	1.8452	0.106222	0.01	0.03	0.14	0.031400492	0.054387247	4.915572077	0.031400492	0.054387247	0.05719238	0.070567999
1.62	0.177	1.821	0.097199	0.01	0.03	0.14	0.02672724	0.046292937	4.843387141	0.02672724	0.046292937	0.048975031	0.060428853
1.62	0.165	1.8062	0.091352	0.01	0.03	0.14	0.023905692	0.041405872	4.79356163	0.023905692	0.041405872	0.043997972	0.054287806
1.62	0.386	2.889	0.13361	0.01	0.03	0.14	0.072058593	0.124809144	5.10714974	0.072058593	0.124809144	0.138816012	0.171281001
1.62	0.396	3.238	0.122298	0.01	0.03	0.14	0.06969143	0.120709098	5.032398465	0.06969143	0.120709098	0.138070386	0.170360995
1.62	0.40064	3.242	0.123578	0.01	0.03	0.14	0.070999257	0.12297432	5.041141027	0.070999257	0.12297432	0.140554278	0.173425797
1.62	0.4169	3.252	0.128198	0.01	0.03	0.14	0.075710846	0.131135032	5.072073333	0.075710846	0.131135032	0.149446829	0.184398055
1.62	0.40645	3.176	0.127975	0.01	0.03	0.14	0.073727614	0.127699974	5.07060449	0.073727614	0.127699974	0.14496153	0.178863775
1.62	0.39658	3.136	0.12646	0.01	0.03	0.14	0.071368397	0.12361369	5.060550426	0.071368397	0.12361369	0.140171812	0.172953884
1.62	0.34693	3.1	0.111913	0.01	0.03	0.14	0.057548489	0.099676908	4.95851911	0.057548489	0.099676908	0.114101804	0.140786866
1.62	0.32052	3.047	0.105192	0.01	0.03	0.14	0.051017075	0.088364165	4.907599094	0.051017075	0.088364165	0.10143735	0.125160567

Figure A8-1. Observed and modeled rating curves and streamflow from Site 8, West Run Watershed, Morgantown, West Virginia, U.S.A

Table A8-3. Polynomial rating equations and R^2 values for observed and modeled rating curves at Site 8, West Run Watershed, Morgantown, WV, U.S.A.

	R² Value	Polynomial Equation
Observed Curve	0.98	$y = 5.2729x^2 - 1.3358x + 0.062$
Manning's Curve (Obs Slope)	0.85	$y = 0.445x^2 + 0.0598x - 0.0133$
Manning's Curve (Calc Slope)	0.85	$y = 0.7708x^2 + 0.1036x - 0.023$
Chezy's Curve (Obs Slope)	0.85	$y = 0.445x^2 + 0.0598x - 0.0133$
Chezy's Curve (Calc Slope)	0.85	$y = 0.7708x^2 + 0.1036x - 0.023$
Dingman and Sharma's Curve (Obs Slope)	0.88	$y = 0.9378x^2 + 0.0967x - 0.0274$
Dingman and Sharma's Curve (Calc Slope)	0.88	$y = 1.1571x^2 + 0.1194x - 0.0339$

Table A8-4. Descriptive statistics for observed and modeled streamflow used to generate the rating curves for Site 8, West Run Watershed, Morgantown, WV, U.S.A.

	Sample Size	Mean (m³/s)	St. Dev.	SE of Mean
Observed	30	0.119	0.124	0.023
Manning's Curve (Obs Slope)	30	0.039	0.024	0.004
Manning's Curve (Calc Slope)	30	0.068	0.0240.042	0.008
Chezy's Curve (Obs Slope)	30	0.039	0.024	0.004
Chezy's Curve (Calc Slope)	30	0.068	0.042	0.008
Dingman and Sharma's Curve (Obs Slope)	30	0.075	0.048	0.009
Dingman and Sharma's Curve (Calc Slope)	30	0.092	0.059	0.011

Table A8-5. P-values of the statistical analyses (post-hoc ANOVA) for observed and modeled rating curves at Site 8, West Run Watershed, Morgantown, WV, U.S.A.

	Observed Curve	Rating Equation Curve	Manning's Curve (Obs Slope)	Manning's Curve (Calc Slope)	Chezy's Curve (Obs Slope)	Chezy's Curve (Calc Slope)	Dingman and Sharma's Curve (Obs Slope)	Dingman and Sharma's Curve (Calc Slope)
Observed Curve	-	1	<0.05*	0.11	<0.05*	0.11	0.25	0.84
Rating Equation Curve	-	-	<0.05*	0.11	<0.05*	0.11	0.26	0.84
Manning's Curve (Obs Slope)	-	-	-	0.78	1	0.78	0.53	0.08
Manning's Curve (Calc Slope)	-	-	-	-	0.78	1	1	0.89
Chezy's Curve (Obs Slope)	-	-	-	-	-	0.78	0.53	0.82
Chezy's Curve (Calc Slope)	-	-	-	-	-	-	1	0.89
Dingman and Sharma's Curve (Obs Slope)	-	-	-	-	-	-	-	0.98
Dingman and Sharma's Curve (Calc Slope)	-	-	-	-	-	-	-	-

*= indicates that the difference of the means is significant at the 0.05 level.

Figure A8-2. Box and whisker plots for the results of the statistical analyses (post-hoc ANOVA) of observed and modeled rating curves at Site 8, West Run Watershed, Morgantown, WV, U.S.A.

Figure A8-3. Cross-sectional profile of WRW Site 8, West Run Watershed, Morgantown, WV, USA (Figure 2). Channel Width of zero (0) represents the left bank facing downstream.

Figure A8-4. Plan view profile of WRW Site 8, West Run Watershed, Morgantown, WV, U.S.A. (Figure 2). Showing the positioning of stilling well in relation to where the streamflow was measured. Along with the channel width at the stilling well, point where cross-sections were performed, and 6.0m upstream and downstream from the stilling well.

Figure A8-5. Photographs showing channel characteristics at Site #8, West Run Watershed, Morgantown, WV, U.S.A. Photo 1 was taken looking upstream in the channel. Photo 2 was taken from the right bank looking downstream.

APPENDIX 9: Site 9

Table A9-1. Streamflow measurements and stage collected at Site 9, West Run Watershed, Morgantown, WV, U.S.A. (Figure 2).

Date	Mean Depth of Cross-Section (m)	Stage(PT in cm)	Barometric Pressure (in cm)	Pressure Corrected Stage (cm)	Stilling Well Offset (cm)	P-Corrected Stage + Offset (cm)	P-Corrected Stage + Offset (m)	SonTec Discharge (m3/s)	Rating Equation Discharge (m3/s)
12/5/2017	0.0975	91.92	79.79	12.13	4.8	16.93	0.1693	0.0297	0.014697514
1/12/2018	0.1113	86.27	69.75	16.52	4.8	21.32	0.2132	0.0772	0.074540896
2/9/2018	0.0955	105.36	92.59	12.77	4.8	17.57	0.1757	0.0524	0.022185834
3/14/2018	0.0797	92.04	79.45	12.59	4.8	17.39	0.1739	0.0293	0.020037102
3/29/2018	0.1348	96.41	80.19	16.22	4.8	21.02	0.2102	0.0691	0.069819466
4/4/2018	0.1577	98.84	79.05	19.79	4.8	24.59	0.2459	0.1516	0.132016542
4/20/2018	0.1019	112.38	96.4	15.98	4.8	20.78	0.2078	0.0824	0.066109066
7/23/2018	0.1030	93.23	81.17	12.06	4.8	16.86	0.1686	0.0123	0.013904074
7/26/2018	0.1189	97.87	83.88	13.99	4.8	18.79	0.1879	0.0166	0.037629082
9/11/2018	0.1680	107.97	89.59	18.38	4.8	23.18	0.2318	0.0594	0.105882826
10/18/2018	0.1548	115.07	99.8	15.27	4.8	20.07	0.2007	0.0179	0.055479833
10/30/2018	0.1536	106.34	89.76	16.58	4.8	21.38	0.2138	0.0404	0.075496306
1/24/2019	0.3362	106.38	69.36	37.02	4.8	41.82	0.4182	0.6264	0.616767946
1/24/2019	0.3332	107.28	69.5	37.78	4.8	42.58	0.4258	0.6227	0.645191186
2/26/2019	0.1637	110.89	94.85	16.04	4.8	20.84	0.2084	0.0566	0.067031104
2/26/2019	0.1606	110.58	95.1	15.48	4.8	20.28	0.2028	0.0612	0.058569616
3/28/2019	0.1329	103.66	90.39	13.27	4.8	18.07	0.1807	0.0159	0.028329634
3/28/2019	0.1323	103.53	90.05	13.48	4.8	18.28	0.1828	0.0164	0.030986816
4/23/2019	0.1515	94.34	83.11	11.23	4.8	16.03	0.1603	0.0259	0.004880854
4/25/2019	0.1338	92.3	79.28	13.02	4.8	17.82	0.1782	0.0255	0.025225546
4/26/2019	0.1990	84.14	65.45	18.69	4.8	23.49	0.2349	0.0855	0.111452922
4/29/2019	0.1402	102.91	90.52	12.39	4.8	17.19	0.1719	0.0306	0.017688762
4/30/2019	0.1786	106.17	90.85	15.32	4.8	20.12	0.2012	0.0804	0.056211376
5/5/2021	0.3840	1025	994.20	30.8	4.8	35.60	0.3560	0.3830	0.4065052
5/5/2021	0.3590	1023	994.45	28.6	4.8	33.40	0.3340	0.3492	0.3416756
5/5/2021	0.3460	1022.3	994.57	27.7	4.8	32.50	0.3250	0.3587	0.31659125
5/5/2021	0.3290	1021.3	994.90	26.4	4.8	31.20	0.3120	0.2794	0.2818312
5/5/2021	0.3150	1021.2	995.17	26	4.8	30.80	0.3080	0.3120	0.271486

Table A9-2. Modeled streamflow at Site 9, West Run Watershed, Morgantown, WV, U.S.A.

Cross-Section Area (m ²)	A (Cross Section area of flow)	P (Wetted Perimeter r)	RH=A/P Hydraulic Radius (m)	Observed Slope (m)	Calculated Slope using ArcGIS (m)	Roughness Coefficient (n)	Manning Discharge (m ³ /s) (Obs Slope)	Manning Discharge (m ³ /s) (Calc Slope)	Chezy Coefficient (C)	Chezy Discharge (m ³ /s) (Obs Slope)	Chezy Discharge (m ³ /s) (Calc Slope)	Dingman & Sharma Discharge (m ³ /s) (Obs. Slope)	Dingman & Sharma Discharge (m ³ /s) (Calc Slope)
5.60	0.148	1.7660	0.083618	0.05	0.032	0.170	0.037141508	0.029713207	3.889866114	0.037141508	0.029713207	0.049753202	0.046493903
5.60	0.218	1.9244	0.113139	0.05	0.032	0.170	0.066991248	0.053592999	4.090908075	0.066991248	0.053592999	0.088538961	0.082738832
5.60	0.158	1.7901	0.088197	0.05	0.032	0.170	0.041146872	0.032917498	3.924578935	0.041146872	0.032917498	0.054972996	0.051371751
5.60	0.155	1.7834	0.08692	0.05	0.032	0.170	0.040007407	0.032005926	3.91505166	0.040007407	0.032005926	0.053488741	0.049984729
5.60	0.213	1.9141	0.111246	0.05	0.032	0.170	0.064785567	0.051828453	4.079423184	0.064785567	0.051828453	0.085679647	0.08006683
5.60	0.270	2.0316	0.132853	0.05	0.032	0.170	0.09243392	0.073947136	4.201905448	0.09243392	0.073947136	0.121475126	0.113517371
5.60	0.264	2.7948	0.094461	0.05	0.032	0.170	0.072023707	0.057618965	3.969720628	0.072023707	0.057618965	0.103268284	0.096503246
5.60	0.196	2.111	0.092847	0.05	0.032	0.170	0.052861244	0.042288995	3.958333528	0.052861244	0.042288995	0.072318229	0.06758071
5.60	0.217	2.0668	0.104993	0.05	0.032	0.170	0.063523829	0.050819063	4.040278404	0.063523829	0.050819063	0.08559651	0.079989139
5.60	0.307	2.165	0.141801	0.05	0.032	0.170	0.109806514	0.087845212	4.247804211	0.109806514	0.087845212	0.145013949	0.135514181
5.60	0.271	2.059	0.131617	0.05	0.032	0.170	0.092231796	0.073785437	4.195366467	0.092231796	0.073785437	0.12159688	0.113631148
5.60	0.281	2.1364	0.13153	0.05	0.032	0.170	0.095592738	0.07647419	4.194900882	0.095592738	0.07647419	0.126842937	0.11853354
5.60	1.021	2.8822	0.354243	0.05	0.032	0.170	0.672351289	0.537881031	4.948056879	0.672351289	0.537881031	0.856312183	0.800215735
5.60	1.010	2.89	0.349481	0.05	0.032	0.170	0.659133131	0.527306505	4.936907617	0.659133131	0.527306505	0.840935449	0.78584632
5.60	0.324	2.308	0.140381	0.05	0.032	0.170	0.11511199	0.092089592	4.240684338	0.11511199	0.092089592	0.153856998	0.143777928
5.60	0.318	2.3022	0.138129	0.05	0.032	0.170	0.111768455	0.089414764	4.22926687	0.111768455	0.089414764	0.149549483	0.139752595
5.60	0.243	2.095	0.11599	0.05	0.032	0.170	0.076019297	0.060815438	4.107915041	0.076019297	0.060815438	0.101720699	0.095057042
5.60	0.242	2.0934	0.115601	0.05	0.032	0.170	0.075537083	0.060429667	4.105615456	0.075537083	0.060429667	0.101093902	0.094471307
5.60	0.265	2.0558	0.128904	0.05	0.032	0.170	0.088945769	0.071156616	4.180824275	0.088945769	0.071156616	0.117462081	0.109767217
5.60	0.255	2.1724	0.117382	0.05	0.032	0.170	0.080409961	0.064327969	4.116086343	0.080409961	0.064327969	0.108152375	0.101067384
5.60	0.364	2.2272	0.163434	0.05	0.032	0.170	0.143119532	0.114495626	4.349521076	0.143119532	0.114495626	0.187427394	0.175149148
5.60	0.267	2.1854	0.122174	0.05	0.032	0.170	0.086470418	0.069176334	4.143631562	0.086470418	0.069176334	0.115988282	0.108389966
5.60	0.354	2.338	0.151411	0.05	0.032	0.170	0.132275226	0.105820181	4.294482834	0.132275226	0.105820181	0.175941627	0.164415807
5.60	0.965	3.2826	0.293974	0.05	0.032	0.170	0.561181001	0.448944801	4.796627246	0.561181001	0.448944801	0.743872586	0.695141982
5.60	0.875	3.1558	0.277267	0.05	0.032	0.170	0.489376587	0.39150127	4.750079105	0.489376587	0.39150127	0.647827165	0.605388433
5.60	0.845	3.131	0.269882	0.05	0.032	0.170	0.464168022	0.371334418	4.728753606	0.464168022	0.371334418	0.615172131	0.574872609
5.60	0.802	3.0958	0.259061	0.05	0.032	0.170	0.428691393	0.342953114	4.696611718	0.428691393	0.342953114	0.569221636	0.531932301
5.60	0.767	3.0672	0.250065	0.05	0.032	0.170	0.400436469	0.320349176	4.669029559	0.400436469	0.320349176	0.532611508	0.497720478

Figure A9-1. Observed and modeled rating curves and streamflow from Site 9, West Run Watershed, Morgantown, West Virginia, U.S.A

Table A9-3. Polynomial rating equations and R^2 values for observed and modeled rating curves at Site 9, West Run Watershed, Morgantown, WV, U.S.A.

	R² Value	Polynomial Equation
Observed Curve	0.98	$y = 5.15x^2 - 0.6067x - 0.0302$
Manning's Curve (Obs Slope)	0.95	$y = 2.926x^2 + 0.9381x - 0.2067$
Manning's Curve (Calc Slope)	0.95	$y = 2.3408x^2 + 0.7505x - 0.1653$
Chezy's Curve (Obs Slope)	0.95	$y = 2.926x^2 + 0.9381x - 0.2067$
Chezy's Curve (Calc Slope)	0.95	$y = 2.3408x^2 + 0.7505x - 0.1653$
Dingman and Sharma's Curve (Obs Slope)	0.94	$y = 2.8521x^2 + 1.738x - 0.3295$
Dingman and Sharma's Curve (Calc Slope)	0.94	$y = 2.6652x^2 + 1.6242x - 0.3079$

Table A9-4. Descriptive statistics for observed and modeled streamflow used to generate the rating curves for Site 9, West Run Watershed, Morgantown, WV, U.S.A.

	Sample Size	Mean (m³/s)	St. Dev.	SE of Mean
Observed	28	0.142	0.179	0.034
Manning's Curve (Obs Slope)	28	0.193	0.203	0.038
Manning's Curve (Calc Slope)	28	0.155	0.162	0.031
Chezy's Curve (Obs Slope)	28	0.193	0.203	0.038
Chezy's Curve (Calc Slope)	28	0.155	0.162	0.031
Dingman and Sharma's Curve (Obs Slope)	28	0.254	0.263	0.05
Dingman and Sharma's Curve (Calc Slope)	28	0.238	0.246	0.046

Table A9-5. P-values of the statistical analyses (post-hoc ANOVA) for observed and modeled rating curves at Site 9, West Run Watershed, Morgantown, WV, U.S.A.

	Observed Curve	Rating Equation Curve	Manning's Curve (Obs Slope)	Manning's Curve (Calc Slope)	Chezy's Curve (Obs Slope)	Chezy's Curve (Calc Slope)	Dingman and Sharma's Curve (Obs Slope)	Dingman and Sharma's Curve (Calc Slope)
Observed Curve	-	1	0.98	1	0.98	1	0.43	0.64
Rating Equation Curve	-	-	0.98	1	0.98	1	0.43	0.64
Manning's Curve (Obs Slope)	-	-	-	1	1	1	0.95	0.99
Manning's Curve (Calc Slope)	-	-	-	-	1	1	0.60	0.79
Chezy's Curve (Obs Slope)	-	-	-	-	-	1	0.95	0.99
Chezy's Curve (Calc Slope)	-	-	-	-	-	-	0.60	0.79
Dingman and Sharma's Curve (Obs Slope)	-	-	-	-	-	-	-	1
Dingman and Sharma's Curve (Calc Slope)	-	-	-	-	-	-	-	-

Figure A9-2. Box and whisker plots for the results of the statistical analyses (post-hoc ANOVA) of observed and modeled rating curves at Site 9, West Run Watershed, Morgantown, WV, U.S.A.

Figure A9-3. Cross-sectional profile of WRW Site 9, West Run Watershed, Morgantown, WV, USA (Figure 2). Channel Width of zero (0) represents the left bank facing downstream.

Figure A9-4. Plan view profile of WRW Site 9, West Run Watershed, Morgantown, WV, U.S.A. (Figure 2). Showing the positioning of stilling well in relation to where the streamflow was measured. Along with the channel width at the stilling well, point where cross-sections were performed, and 6.0m upstream and downstream from the stilling well.

Figure A9-5. Photographs showing channel characteristics at Site #9, West Run Watershed, Morgantown, WV, U.S.A. Photo 1 was taken looking upstream in the channel. Photo 2 was taken from the right bank looking upstream.

APPENDIX 10: Site 10

Table A10-1. Streamflow measurements and stage collected at Site 10, West Run Watershed, Morgantown, WV, U.S.A. (Figure 2).

Date	Mean Depth of Cross-Section (m)	Stage(PT in cm)	Barometric Pressure (in cm)	Pressure Corrected Stage (cm)	Stilling Well Offset (cm)	P-Corrected Stage + Offset (cm)	P-Corrected Stage + Offset (m)	SonTec Discharge (m ³ /s)	Rating Equation Discharge (m ³ /s)
1/23/2018	0.1136	98.4	74.36	24.04	5.7	29.755	0.29755	0.2171	0.152898656
2/9/2018	0.0999	115.95	93.35	22.6	5.7	28.315	0.28315	0.1710	0.121922274
3/10/2018	0.0752	103.31	83.49	19.82	5.7	25.535	0.25535	0.1061	0.071414889
3/14/2018	0.0716	99.28	79.8	19.48	5.7	25.195	0.25195	0.0716	0.066078135
3/29/2018	0.1216	105.83	79.66	26.17	5.7	31.885	0.31885	0.2645	0.204742161
4/20/2018	0.1102	121.27	96.3	24.97	5.7	30.685	0.30685	0.2189	0.174650413
7/23/2018	0.0814	97.38	81.11	16.27	5.7	21.985	0.21985	0.0203	0.02472087
7/26/2018	0.0948	101.58	83.81	17.77	5.7	23.485	0.23485	0.0390	0.042014599
9/11/2018	0.1378	112.36	89.12	23.24	5.7	28.955	0.28955	0.1558	0.135283928
10/4/2018	0.1091	104.94	84.75	20.19	5.7	25.905	0.25905	0.0627	0.077430654
10/30/2018	0.1222	111.36	89.78	21.58	5.7	27.295	0.27295	0.0981	0.101968558
12/4/2018	0.1186	106.34	84.03	22.31	5.7	28.025	0.28025	0.0845	0.116081441
12/17/2018	0.1606	108.37	82.39	25.98	5.7	31.695	0.31695	0.1961	0.199825603
1/24/2019	0.4566	130.8	69.56	61.24	5.7	66.955	0.66955	2.0578	2.091893987
1/24/2019	0.5026	130.15	69.71	60.44	5.7	66.155	0.66155	1.9741	2.027125134
2/26/2019	0.1518	121.42	95.18	26.24	5.7	31.955	0.31955	0.1631	0.206567943
2/26/2019	0.1451	121.61	95.32	26.29	5.7	32.005	0.32005	0.1604	0.207876827
3/28/2019	0.1091	111.1	90.73	20.37	5.7	26.085	0.26085	0.0516	0.080435675
4/15/2019	0.2036	104.89	72.84	32.05	5.7	37.765	0.37765	0.3807	0.385172995
4/15/2019	0.1978	105.33	73.3	32.03	5.7	37.745	0.37745	0.3645	0.384466434
4/23/2019	0.1061	102.03	82.98	19.05	5.7	24.765	0.24765	0.0629	0.059591021
4/23/2019	0.1155	101.68	82.53	19.15	5.7	24.865	0.24865	0.0600	0.061073509
4/25/2019	0.1061	99.94	79.32	20.62	5.7	26.335	0.26335	0.0618	0.08469448
4/25/2019	0.1079	100.04	79.37	20.67	5.7	26.385	0.26385	0.0560	0.085558125
4/26/2019	0.1926	94.96	65.97	28.99	5.7	34.705	0.34705	0.2972	0.284438919
4/26/2019	0.1835	94.48	66.34	28.14	5.7	33.855	0.33855	0.2708	0.25909024
4/29/2019	0.1158	110.28	90.49	19.79	5.7	25.505	0.25505	0.0729	0.070936631
4/29/2019	0.1140	110.36	90.55	19.81	5.7	25.525	0.25525	0.0679	0.071255311
4/30/2019	0.1277	112.91	90.89	22.02	5.7	27.735	0.27735	0.1162	0.110373863
4/30/2020	0.2374	1026.7	987.41	44.958	0.0	44.958	0.44958	0.6060	0.680391478
2/28/2021	0.1590	1033.8	1001.10	32.7	5.7	38.415	0.38415	0.3937	0.408481243
2/28/2021	0.1540	1033.1	1001.06	32	5.7	37.715	0.37715	0.4038	0.383407781
2/28/2021	0.1530	1032.6	1001.13	31.5	5.7	37.215	0.37215	0.3855	0.36597351
6/13/2021	0.2243	1036.6	995.36	41.2	5.7	46.915	0.46915	0.6942	0.774897876
6/13/2021	0.2137	1033	995.08	37.9	5.7	43.615	0.43615	0.5788	0.619047169
6/13/2021	0.1954	1032.3	995.26	37	5.7	42.715	0.42715	0.5327	0.579537097
6/13/2021	0.1942	1028.8	995.47	33.3	5.7	39.015	0.39015	0.4312	0.430590729
10/16/2021	0.3240	1044.49	991.39	53.1	5.7	58.815	0.58815	1.4710	1.480205345
10/16/2021	0.3260	1043.43	991.43	52	5.7	57.715	0.57715	1.5325	1.405597045
10/16/2021	0.3120	1041.52	991.22	50.3	5.7	56.015	0.56015	1.3379	1.294064371
10/16/2021	0.2870	1039.55	991.45	48.1	5.7	53.815	0.53815	1.2483	1.156525389

Table A10-2. Modeled streamflow at Site 10, West Run Watershed, Morgantown, WV, U.S.A.

Cross-Section Area (m ²)	A (Cross Section area of flow)	P (Wetted Perimeter)	RH=A/P Hydraulic Radius (m)	Observed Slope (m)	Calculated Slope using ArcGIS (m)	Roughness Coefficient (n)	Manning Discharge (m ³ /s) (Obs Slope)	Manning Discharge (m ³ /s) (Calc Slope)	Chezy Coefficient (C)	Chezy Discharge (m ³ /s) (Obs Slope)	Chezy Discharge (m ³ /s) (Calc Slope)	Dingman & Sharma Discharge (m ³ /s) (Obs. Slope)	Dingman & Sharma Discharge (m ³ /s) (Calc Slope)
6.96	0.352	2.1822	0.161453	0.01	0.005	0.085	0.122902963	0.086905519	8.681382645	0.122902963	0.086905519	0.134532699	0.114425686
6.96	0.329	2.1426	0.153719	0.01	0.005	0.085	0.111187818	0.07862166	8.61064008	0.111187818	0.07862166	0.121882359	0.103666043
6.96	0.285	2.0609	0.138283	0.01	0.005	0.085	0.089657506	0.06339743	8.460109899	0.089657506	0.06339743	0.098595096	0.083859252
6.96	0.280	2.0505	0.136341	0.01	0.005	0.085	0.087125287	0.061606881	8.440193429	0.087125287	0.061606881	0.095853161	0.081527122
6.96	0.386	2.2377	0.172644	0.01	0.005	0.085	0.140917077	0.099643421	8.778891489	0.140917077	0.099643421	0.153952787	0.130943283
6.96	0.638	6.0114	0.106132	0.01	0.005	0.085	0.168253893	0.118973468	8.095094375	0.168253893	0.118973468	0.228259796	0.194144502
6.96	0.279	3.5916	0.077681	0.01	0.005	0.085	0.059758007	0.042255292	7.684821441	0.059758007	0.042255292	0.076358407	0.06496035
6.96	0.383	4.2284	0.090578	0.01	0.005	0.085	0.090878606	0.064260878	7.88408914	0.090878606	0.064260878	0.117743786	0.100146013
6.96	0.683	5.2288	0.130623	0.01	0.005	0.085	0.206862083	0.146273582	8.380131878	0.206862083	0.146273582	0.268670327	0.228515348
6.96	0.516	4.9422	0.104407	0.01	0.005	0.085	0.134601645	0.095177736	8.073018948	0.134601645	0.095177736	0.176793626	0.150370372
6.96	0.596	5.1214	0.116374	0.01	0.005	0.085	0.167134347	0.11818183	8.220356796	0.167134347	0.11818183	0.218647057	0.185968465
6.96	0.578	5.1142	0.113019	0.01	0.005	0.085	0.158955539	0.11239854	8.180366522	0.158955539	0.11239854	0.208467403	0.177310243
6.96	0.808	5.3504	0.151017	0.01	0.005	0.085	0.269572658	0.190616655	8.585229829	0.269572658	0.190616655	0.346769042	0.294941571
6.96	2.47	6.3232	0.390625	0.01	0.005	0.085	1.55280904	1.098001802	10.05868204	1.55280904	1.098001802	1.88093717	1.599815716
6.96	2.479	6.323	0.392061	0.01	0.005	0.085	1.562283446	1.104701219	10.06483436	1.562283446	1.104701219	1.891753093	1.609015111
6.96	0.74	5.1806	0.142841	0.01	0.005	0.085	0.237892399	0.168215329	8.505953758	0.237892399	0.168215329	0.305904749	0.260184781
6.96	0.742	5.1877	0.143031	0.01	0.005	0.085	0.238746867	0.168819529	8.507838741	0.238746867	0.168819529	0.307038016	0.261148671
6.96	0.516	4.9426	0.104398	0.01	0.005	0.085	0.134594382	0.0951726	8.072910054	0.134594382	0.0951726	0.176787903	0.150365504
6.96	1.023	5.436	0.18819	0.01	0.005	0.085	0.395233879	0.279472556	8.905953814	0.395233879	0.279472556	0.499412423	0.424771149
6.96	1.022	5.43	0.188214	0.01	0.005	0.085	0.394880797	0.279222889	8.906141386	0.394880797	0.279222889	0.498865047	0.424305583
6.96	0.517	5.0892	0.101588	0.01	0.005	0.085	0.132423674	0.093637678	8.036271088	0.132423674	0.093637678	0.175265956	0.149071024
6.96	0.517	5.0892	0.101588	0.01	0.005	0.085	0.132423674	0.093637678	8.036271088	0.132423674	0.093637678	0.175265956	0.149071024
6.96	0.518	5.0894	0.10178	0.01	0.005	0.085	0.132847367	0.093937274	8.038807024	0.132847367	0.093937274	0.175796744	0.149522482
6.96	0.526	5.0928	0.103283	0.01	0.005	0.085	0.136223772	0.096324753	8.058470024	0.136223772	0.096324753	0.180038206	0.153130022
6.96	0.954	5.3384	0.178705	0.01	0.005	0.085	0.356085501	0.251790473	8.829523866	0.356085501	0.251790473	0.450714881	0.383351854
6.96	0.923	5.396	0.171053	0.01	0.005	0.085	0.334607714	0.236603383	8.765352129	0.334607714	0.236603383	0.426059495	0.362381416
6.96	0.565	5.1086	0.110598	0.01	0.005	0.085	0.153153604	0.108295952	8.150898763	0.153153604	0.108295952	0.201227901	0.171152744
6.96	0.555	5.1048	0.108721	0.01	0.005	0.085	0.148736272	0.105172426	8.12768349	0.148736272	0.105172426	0.195712299	0.166461494
6.96	0.633	5.2086	0.12153	0.01	0.005	0.085	0.182714601	0.129198733	8.2799591	0.182714601	0.129198733	0.238757148	0.203072938
6.96	0.595	2.4924	0.238704	0.01	0.005	0.085	0.269335315	0.190448827	9.265969828	0.269335315	0.190448827	0.290828599	0.247361885
6.96	0.94442	6.262	0.150818	0.01	0.005	0.085	0.314809376	0.222603844	8.583342181	0.314809376	0.222603844	0.416184924	0.353982681
6.96	0.91509	6.252	0.146368	0.01	0.005	0.085	0.299002471	0.211426675	8.540603255	0.299002471	0.211426675	0.396288741	0.337060145
6.96	0.89855	6.173	0.145561	0.01	0.005	0.085	0.292518926	0.206842116	8.532744395	0.292518926	0.206842116	0.387043871	0.329196997
6.96	1.47019	7.001	0.209997	0.01	0.005	0.085	0.611078208	0.432097545	9.070195307	0.611078208	0.432097545	0.798456346	0.679120511
6.96	1.38774	6.92	0.20054	0.01	0.005	0.085	0.559358861	0.395526444	9.000806175	0.559358861	0.395526444	0.732562971	0.62307544
6.96	1.25071	6.791	0.184172	0.01	0.005	0.085	0.476306262	0.336799388	8.87397545	0.476306262	0.336799388	0.626744633	0.533072518
6.96	1.21238	6.636	0.182697	0.01	0.005	0.085	0.459241819	0.324733004	8.862096442	0.459241819	0.324733004	0.602334824	0.512310955
6.96	1.94864	6.668	0.292238	0.01	0.005	0.085	1.009570617	0.713874229	9.583785345	1.009570617	0.713874229	1.268195885	1.078653631
6.96	1.9858	6.748	0.29428	0.01	0.005	0.085	1.033610396	0.73087292	9.594915323	1.033610396	0.73087292	1.300227271	1.105897664
6.96	1.87548	6.644	0.282282	0.01	0.005	0.085	0.949471764	0.671377923	9.528580555	0.949471764	0.671377923	1.195833631	1.017106508
6.96	1.70709	6.518	0.261904	0.01	0.005	0.085	0.822114297	0.581322594	9.410327787	0.822114297	0.581322594	1.039274693	0.883946585

Figure A10-1. Observed and modeled rating curves and streamflow from Site 10, West Run Watershed, Morgantown, West Virginia, USA.

Table A10-3. Polynomial rating equations and R^2 values for observed and modeled rating curves at Site 10, West Run Watershed, Morgantown, WV, U.S.A.

	R² Value	Polynomial Equation
Observed Curve	0.99	$y = 7.9224x^2 - 2.4494x + 0.1803$
Manning's Curve (Obs Slope)	0.97	$y = 5.985x^2 - 2.1592x + 0.2923$
Manning's Curve (Calc Slope)	0.97	$y = 4.2321x^2 - 1.5268x + 0.2067$
Chezy's Curve (Obs Slope)	0.97	$y = 5.985x^2 - 2.1592x + 0.2923$
Chezy's Curve (Calc Slope)	0.97	$y = 4.2321x^2 - 1.5268x + 0.2067$
Dingman and Sharma's Curve (Obs Slope)	0.97	$y = 6.6746x^2 - 2.0624x + 0.2565$
Dingman and Sharma's Curve (Calc Slope)	0.97	$y = 5.677x^2 - 1.7542x + 0.2181$

Table A10-4. Descriptive statistics for observed and modeled streamflow used to generate the rating curves for Site 10, West Run Watershed, Morgantown, WV, U.S.A.

	Sample Size	Mean (m³/s)	St. Dev.	SE of Mean
Observed	41	0.428	0.535	0.084
Manning's Curve (Obs Slope)	41	0.369	0.372	0.058
Manning's Curve (Calc Slope)	41	0.261	0.263	0.041
Chezy's Curve (Obs Slope)	41	0.369	0.372	0.058
Chezy's Curve (Calc Slope)	41	0.261	0.263	0.041
Dingman and Sharma's Curve (Obs Slope)	41	0.465	0.457	0.071
Dingman and Sharma's Curve (Calc Slope)	41	0.396	0.389	0.061

Table A10-5. P-values of the statistical analyses (post-hoc ANOVA) for observed and modeled rating curves at Site 10, West Run Watershed, Morgantown, WV, U.S.A.

	Observed Curve	Rating Equation Curve	Manning's Curve (Obs Slope)	Manning's Curve (Calc Slope)	Chezy's Curve (Obs Slope)	Chezy's Curve (Calc Slope)	Dingman and Sharma's Curve (Obs Slope)	Dingman and Sharma's Curve (Calc Slope)
Observed Curve	-	1	1	0.59	1	0.59	1	1
Rating Equation Curve	-	-	1	0.59	1	0.59	1	1
Manning's Curve (Obs Slope)	-	-	-	0.93	1	0.93	0.96	1
Manning's Curve (Calc Slope)	-	-	-	-	0.93	1	0.32	0.81
Chezy's Curve (Obs Slope)	-	-	-	-	-	0.93	0.96	1
Chezy's Curve (Calc Slope)	-	-	-	-	-	-	0.32	0.81
Dingman and Sharma's Curve (Obs Slope)	-	-	-	-	-	-	-	0.99
Dingman and Sharma's Curve (Calc Slope)	-	-	-	-	-	-	-	-

Figure A10-2. Box and whisker plots for the results of the statistical analyses (post-hoc ANOVA) of observed and modeled rating curves at Site 10, West Run Watershed, Morgantown, WV, U.S.A.

Figure A10-3. Cross-sectional profile of WRW Site 10, West Run Watershed, Morgantown, WV, USA (Figure 2). Channel Width of zero (0) represents the left bank facing downstream.

Figure A10-4. Plan view profile of WRW Site 10, West Run Watershed, Morgantown, WV, U.S.A. (Figure 2). Showing the positioning of stilling well in relation to where the streamflow was measured. Along with the channel width at the stilling well, point where cross-sections were performed, and 15.5m upstream and downstream from the stilling well.

Figure A10-5. Photographs showing channel characteristics at Site #10, West Run Watershed, Morgantown, WV, U.S.A. Photo 1 was taken looking upstream in the channel. Photo 2 was taken from the right bank looking downstream.

APPENDIX 11: Site 11

Table A11-1. Streamflow measurements and stage collected at Site 11, West Run Watershed, Morgantown, WV, U.S.A. (Figure 2).

Date	Mean Depth of Cross-Section (m)	Stage(PT in cm)	Barometric Pressure (in cm)	Pressure Corrected Stage (cm)	Stilling Well Offset (cm)	P-Corrected Stage + Offset (cm)	P-Corrected Stage + Offset (m)	SonTec Discharge (m3/s)	Rating Equation Discharge (m3/s)
12/5/2017	0.3200	105.95	79.77	26.18	8.4	34.58	0.3458	0.0202	0.01191721
2/9/2018	0.3187	118.19	93.6	24.59	8.4	32.99	0.3299	0.0158	0.009809573
4/4/2018	0.3200	115.2	80.05	35.15	8.4	43.55	0.4355	0.0699	0.060252212
2/6/2019	0.3447	128.13	78.76	49.37	8.4	57.77	0.5777	0.2867	0.263752783
2/6/2019	0.3659	128.53	78.45	50.08	8.4	58.48	0.5848	0.2958	0.277991966
3/19/2019	0.2317	127.46	97.04	30.42	8.4	38.82	0.3882	0.0144	0.027048286
3/19/2019	0.2371	127.39	96.84	30.55	8.4	38.95	0.3895	0.0177	0.027730787
4/23/2019	0.1795	107.75	81.2	26.55	8.4	34.95	0.3495	0.0154	0.012686687
4/23/2019	0.1868	107.42	80.76	26.66	8.4	35.06	0.3506	0.0159	0.012935765
4/26/2019	0.2304	100.99	67.72	33.27	8.4	41.67	0.4167	0.0344	0.044993389
4/26/2019	0.2286	101.07	67.94	33.13	8.4	41.53	0.4153	0.0309	0.043965901
5/13/2019	0.2134	108.13	74.5	33.63	8.4	42.03	0.4203	0.0357	0.047704756
5/13/2019	0.2216	108.22	74.65	33.57	8.4	41.97	0.4197	0.0387	0.047245936
5/14/2019	0.2176	113.47	82.24	31.23	8.4	39.63	0.3963	0.0295	0.031512712
5/14/2019	0.2204	113.32	82.13	31.19	8.4	39.59	0.3959	0.0305	0.031280396
5/15/2019	0.1914	112.11	84.17	27.94	8.4	36.34	0.3634	0.0248	0.016518677
8/16/2021	0.2720	1042.8	1004.34	38.5	8.4	46.9	0.4690	0.1244	0.094183147
8/16/2021	0.2480	1049.3	1004.53	44.8	8.4	53.2	0.5320	0.1731	0.18138444
8/16/2021	0.1940	1050	1004.61	45.4	8.4	53.8	0.5380	0.2008	0.19128219
8/16/2021	0.2490	1056	1004.68	51.3	8.4	59.7	0.5970	0.2887	0.303365228
8/16/2021	0.2350	1056.1	1004.67	51.4	8.4	59.8	0.5980	0.2794	0.30549579

Table A11-2. Modeled streamflow at Site 11, West Run Watershed, Morgantown, WV, U.S.A.

Cross-Section Area (m ²)	A (Cross Section area of flow)	P (Wetted Perimeter)	RH=A/P Hydraulic Radius (m)	Observed Slope (m)	Calculated Slope using ArcGIS (m)	Roughness Coefficient (n)	Manning Discharge (m ³ /s) (Obs Slope)	Manning Discharge (m ³ /s) (Calc Slope)	Chezy Coefficient (C)	Chezy Discharge (m ³ /s) (Obs Slope)	Chezy Discharge (m ³ /s) (Calc Slope)	Dingman & Sharma Discharge (m ³ /s) (Obs. Slope)	Dingman & Sharma Discharge (m ³ /s) (Calc Slope)
1.03	0.429	2.3022	0.186485	0.035	0.04	0.185	0.141714264	0.15149892	4.085722602	0.141714264	0.15149892	0.227328432	0.232081484
1.03	0.404	2.2649	0.178355	0.035	0.04	0.185	0.129434916	0.138371746	4.055481913	0.129434916	0.138371746	0.207910738	0.212257799
1.03	0.572	2.4720	0.231581	0.035	0.04	0.185	0.218315351	0.233388928	4.235897213	0.218315351	0.233388928	0.34742485	0.354688915
1.03	0.771	3.6616	0.210564	0.035	0.04	0.185	0.27595546	0.295008796	4.169258774	0.27595546	0.295008796	0.474245436	0.484161104
1.03	0.784	3.662	0.214091	0.035	0.04	0.185	0.28373321	0.30332356	4.180817646	0.28373321	0.30332356	0.486863048	0.497042529
1.03	0.512	2.6736	0.191502	0.035	0.04	0.185	0.172020923	0.183898102	4.103841003	0.172020923	0.183898102	0.282473726	0.288379773
1.03	0.524	2.6846	0.195187	0.035	0.04	0.185	0.178304121	0.190615124	4.116899087	0.178304121	0.190615124	0.292476693	0.298591884
1.03	0.383	2.493	0.15363	0.035	0.04	0.185	0.11109949	0.118770351	3.95586098	0.11109949	0.118770351	0.183999966	0.187847093
1.03	0.395	2.5	0.158	0.035	0.04	0.185	0.116742982	0.124803497	3.974395839	0.116742982	0.124803497	0.192932864	0.196966763
1.03	0.527	2.7468	0.19186	0.035	0.04	0.185	0.177280905	0.189521259	4.105116952	0.177280905	0.189521259	0.292423496	0.298537576
1.03	0.523	2.7432	0.190653	0.035	0.04	0.185	0.175197052	0.187293527	4.100803641	0.175197052	0.187293527	0.289091386	0.295135796
1.03	0.487	2.7124	0.179546	0.035	0.04	0.185	0.156738158	0.167560139	4.059982321	0.156738158	0.167560139	0.259583178	0.265010622
1.03	0.507	2.7292	0.185769	0.035	0.04	0.185	0.166923949	0.178449208	4.083103334	0.166923949	0.178449208	0.275866114	0.281634007
1.03	0.465	2.5694	0.180976	0.035	0.04	0.185	0.150451343	0.160839251	4.065355014	0.150451343	0.160839251	0.246664011	0.251821338
1.03	0.47	2.5748	0.182538	0.035	0.04	0.185	0.152943042	0.163502989	4.071183376	0.152943042	0.163502989	0.250638344	0.255878767
1.03	0.423	2.5932	0.163119	0.035	0.04	0.185	0.127704313	0.136521653	3.995572334	0.127704313	0.136521653	0.211755147	0.216182588
1.03	0.51735	2.449	0.211249	0.035	0.04	0.185	0.185571179	0.198383935	4.171518907	0.185571179	0.198383935	0.297387297	0.303605161
1.03	0.56671	2.782	0.203706	0.035	0.04	0.185	0.19840792	0.212106988	4.1463144	0.19840792	0.212106988	0.326158567	0.33297799
1.03	0.68051	3.893	0.174803	0.035	0.04	0.185	0.215144481	0.229999125	4.04190985	0.215144481	0.229999125	0.3802506	0.388200995
1.03	0.72116	3.394	0.212481	0.035	0.04	0.185	0.259681166	0.277610843	4.175561683	0.259681166	0.277610843	0.440082401	0.449283778
1.03	0.7171	3.518	0.203837	0.035	0.04	0.185	0.251168174	0.268510072	4.14676018	0.251168174	0.268510072	0.429975344	0.438965399

Figure A11-1. Observed and modeled rating curves and streamflow from Site 11, West Run Watershed, Morgantown, West Virginia, U.S.A.

Table A11-3. Polynomial rating equations and R^2 values for observed and modeled rating curves at Site 11, West Run Watershed, Morgantown, WV, U.S.A.

	R² Value	Polynomial Equation
Observed Curve	0.98	$y = 3.8475x^2 - 2.4672x + 0.405$
Manning's Curve (Obs Slope)	0.87	$y = -0.1135x^2 + 0.6359x - 0.0757$
Manning's Curve (Calc Slope)	0.87	$y = -0.1213x^2 + 0.6798x - 0.081$
Chezy's Curve (Obs Slope)	0.87	$y = -0.1135x^2 + 0.6359x - 0.0757$
Chezy's Curve (Calc Slope)	0.87	$y = -0.1213x^2 + 0.6798x - 0.081$
Dingman and Sharma's Curve (Obs Slope)	0.89	$y = 0.253x^2 + 0.714x - 0.0638$
Dingman and Sharma's Curve (Calc Slope)	0.89	$y = 0.2583x^2 + 0.7289x - 0.0651$

Table A11-4. Descriptive statistics for observed and modeled streamflow used to generate the rating curves for Site 11, West Run Watershed, Morgantown, WV, U.S.A.

	Sample Size	Mean (m³/s)	St. Dev.	SE of Mean
Observed	21	0.097	0.108	0.024
Manning's Curve (Obs Slope)	21	0.183	0.051	0.011
Manning's Curve (Calc Slope)	21	0.196	0.055	0.012
Chezy's Curve (Obs Slope)	21	0.183	0.051	0.011
Chezy's Curve (Calc Slope)	21	0.196	0.055	0.012
Dingman and Sharma's Curve (Obs Slope)	21	0.305	0.091	0.02
Dingman and Sharma's Curve (Calc Slope)	21	0.311	0.093	0.02

Table A11-5. P-values of the statistical analyses (post-hoc ANOVA) for observed and modeled rating curves at Site 11, West Run Watershed, Morgantown, WV, U.S.A.

	Observed Curve	Rating Equation Curve	Manning's Curve (Obs Slope)	Manning's Curve (Calc Slope)	Chezy's Curve (Obs Slope)	Chezy's Curve (Calc Slope)	Dingman and Sharma's Curve (Obs Slope)	Dingman and Sharma's Curve (Calc Slope)
Observed Curve	-	1	<0.05*	<0.05*	<0.05*	<0.05*	<0.05*	<0.05*
Rating Equation Curve	-	-	<0.05*	<0.05*	<0.05*	<0.05*	<0.05*	<0.05*
Manning's Curve (Obs Slope)	-	-	-	1	1	1	<0.05*	<0.05*
Manning's Curve (Calc Slope)	-	-	-	-	1	1	<0.05*	<0.05*
Chezy's Curve (Obs Slope)	-	-	-	-	-	1	<0.05*	<0.05*
Chezy's Curve (Calc Slope)	-	-	-	-	-	-	<0.05*	<0.05*
Dingman and Sharma's Curve (Obs Slope)	-	-	-	-	-	-	-	1
Dingman and Sharma's Curve (Calc Slope)	-	-	-	-	-	-	-	-

*= indicates that the difference of the means is significant at the 0.05 level.

Figure A11-2. Box and whisker plots for the results of the statistical analyses (post-hoc ANOVA) of observed and modeled rating curves at Site 11, West Run Watershed, Morgantown, WV, U.S.A.

Figure A11-3. Cross-sectional profile of WRW Site 11, West Run Watershed, Morgantown, WV, USA (Figure 2). Channel Width of zero (0) represents the left bank facing downstream.

Figure A11-4. Plan view profile of WRW Site 11, West Run Watershed, Morgantown, WV, U.S.A. (Figure 2). Showing the positioning of stilling well in relation to where the streamflow was measured. Along with the channel width at the stilling well, point where cross-sections were performed, and 15.5m upstream and downstream from the stilling well.

Figure A11-5. Photographs showing channel characteristics at Site #11, West Run Watershed, Morgantown, WV, U.S.A. Photo 1 was taken looking upstream in the channel. Photo 2 was taken from the right bank looking downstream.

APPENDIX 12: Site 12

Table A12-1. Streamflow measurements and stage collected at Site 12, West Run Watershed, Morgantown, WV, U.S.A. (Figure 2).

Date	Mean Depth of Cross-Section (m)	Stage(PT in cm)	Barometric Pressure (in cm)	Pressure Corrected Stage (cm)	Stilling Well Offset (cm)	P-Corrected Stage + Offset (cm)	P-Corrected Stage + Offset (m)	SonTec Discharge (m3/s)	Rating Equation Discharge (m3/s)
1/21/2018	0.0909	106.88	88.89	17.99	3.6	21.59	0.2159	0.0248	0.066268358
3/23/2018	0.0898	103.47	88.89	14.58	3.6	18.18	0.1818	0.0191	0.030487213
3/29/2018	0.1137	97.89	78.35	19.54	3.6	23.14	0.2314	0.0684	0.083160779
3/30/2018	0.1639	106.76	83.83	22.93	3.6	26.53	0.2653	0.1240	0.121474668
4/5/2018	0.1350	107.42	88.03	19.39	3.6	22.99	0.2299	0.0506	0.081508867
6/14/2018	0.1299	101.46	85.74	15.72	3.6	19.32	0.1932	0.0195	0.042237763
6/14/2018	0.1283	101.27	85.4	15.87	3.6	19.47	0.1947	0.0197	0.043799701
6/14/2018	0.1329	101.24	85.56	15.68	3.6	19.28	0.1928	0.0167	0.041821868
7/23/2018	0.0789	94.34	80.77	13.57	3.6	17.17	0.1717	0.0057	0.020254093
7/23/2018	0.0759	94.36	80.72	13.64	3.6	17.24	0.1724	0.0050	0.020957942
7/26/2018	0.0930	98.64	84.29	14.35	3.6	17.95	0.1795	0.0077	0.028142238
9/11/2018	0.2219	106.33	89.03	17.3	3.6	20.9	0.2090	0.0456	0.058874813
9/20/2018	0.1603	102.61	89.04	13.57	3.6	17.17	0.1717	0.0144	0.020254093
9/20/2018	0.1658	102.79	89.08	13.71	3.6	17.31	0.1731	0.0169	0.021662592
10/2/2018	0.1756	99.69	87.17	12.52	3.6	16.12	0.1612	0.0171	0.009792462
10/2/2018	0.1689	99.55	87.03	12.52	3.6	16.12	0.1612	0.0124	0.009792462
10/16/2018	0.1934	104.13	91.41	12.72	3.6	16.32	0.1632	0.0137	0.011771261
10/16/2018	0.1942	104.28	91.52	12.76	3.6	16.36	0.1636	0.0150	0.012167805
10/18/2018	0.1689	110.41	99.38	11.03	3.6	14.63	0.1463	0.0089	0.004743815
10/18/2018	0.1692	110.48	99.4	11.08	3.6	14.68	0.1468	0.0088	0.004261904
10/25/2018	0.1585	101.01	90.44	10.57	3.6	14.17	0.1417	0.0084	0.009158221
10/25/2018	0.1555	100.74	90.16	10.58	3.6	14.18	0.1418	0.0088	0.009062623
10/30/2018	0.2201	103.7	88.73	14.97	3.6	18.57	0.1857	0.0159	0.034483235
11/1/2018	0.2048	87.68	76.07	11.61	3.6	15.21	0.1521	0.0113	0.00087147
11/13/2018	0.2155	103.18	86.85	16.33	3.6	19.93	0.1993	0.0200	0.048612574
2/26/2019	0.24902	111.74	94.35	17.39	3.6	20.99	0.2099	0.0246	0.059834776
10/31/2019	0.1319	92.38	69.57	22.81	3.6	26.41	0.2641	0.0577	0.120086358
10/31/2019	0.1757	92.82	69.6	23.22	3.6	26.82	0.2682	0.0956	0.124839469
8/28/2020	0.127	1006.9	995.97	10.9	3.6	14.5	0.1450	0.0433	0.00599487
8/28/2020	0.13	1006.8	996.15	10.6	3.6	14.2	0.1420	0.0385	0.008871379
2/24/2021	0.168	1010.4	992.85	17.5	3.6	21.1	0.2110	0.0970	0.061009861
2/24/2021	0.164	1010.1	992.78	17.3	3.6	20.9	0.2090	0.0929	0.058874813
2/24/2021	0.17	1010.4	992.73	17.7	3.6	21.3	0.2130	0.0980	0.063151447
2/24/2021	0.178	1010.2	992.74	17.5	3.6	21.1	0.2110	0.0864	0.061009861
6/14/2021	0.237	1032	993.34	38.7	3.6	42.3	0.4230	0.3430	0.324399679
6/14/2021	0.218	1025.9	993.33	32.6	3.6	36.2	0.3620	0.2796	0.241085757
6/14/2021	0.382	1066.8	993.57	73.2	3.6	76.8	0.7680	0.9038	0.910066573
6/14/2021	0.37	1058.5	993.39	65.1	3.6	68.7	0.6870	0.7266	0.755087167
6/14/2021	0.369	1050.8	993.24	57.6	3.6	61.2	0.6120	0.5599	0.621148957
6/14/2021	0.356	1040.7	992.96	47.7	3.6	51.3	0.5130	0.5237	0.458427607
6/14/2021	0.309	1038.7	993.07	45.6	3.6	49.2	0.4920	0.4462	0.425970301
6/14/2021	0.321	1035.8	993.34	42.5	3.6	46.1	0.4610	0.4271	0.379374461
9/1/2021	0.524	1047.3	988.12	59.2	3.6	62.8	0.6280	0.6081	0.648951005
9/1/2021	0.546	1047.9	988.04	59.9	3.6	63.5	0.6350	0.6405	0.66124597
9/1/2021	0.547	1053.3	987.99	65.3	3.6	68.9	0.6890	0.7391	0.758784701
9/1/2021	0.554	1054.2	987.97	66.2	3.6	69.8	0.6980	0.8633	0.775504509

Table A12-2. Modeled streamflow at Site 12, West Run Watershed, Morgantown, WV, U.S.A.

Cross- Section Area (m ²)	A (Cross Section area of flow)	P (Wetted Perimete r)	RH=A/P Hydraulic Radius (m)	Observed Slope (m)	Calculated Slope using ArcGIS (m)	Roughness Coefficient (n)	Manning Discharge (m ³ /s) (Obs Slope)	Manning Discharge (m ³ /s) (Calc Slope)	Chezy Coefficient (C)	Chezy Discharge (m ³ /s) (Obs Slope)	Chezy Discharge (m ³ /s) (Calc Slope)	Dingman & Sharma Discharge (m ³ /s) (Obs. Slope)	Dingman & Sharma Discharge (m ³ /s) (Calc Slope)
0.88	0.222	1.9336	0.114829	0.02	0.059	0.095	0.078086597	0.134118134	7.338683886	0.078086597	0.134118134	0.078499773	0.093232773
0.88	0.168	1.8128	0.092464	0.02	0.059	0.095	0.051021742	0.087632719	7.078450729	0.051021742	0.087632719	0.051762066	0.061476877
0.88	0.247	1.9852	0.124303	0.02	0.059	0.095	0.091495898	0.157149365	7.436296353	0.091495898	0.157149365	0.09171653	0.108930078
0.88	0.301	2.0909	0.143894	0.02	0.059	0.095	0.12298686	0.211236869	7.619913493	0.12298686	0.211236869	0.12270092	0.145729683
0.88	0.244	1.9803	0.123402	0.02	0.059	0.095	0.090170037	0.154872125	7.427286437	0.090170037	0.154872125	0.090410382	0.10737879
0.88	0.186	1.8543	0.100205	0.02	0.059	0.095	0.059673694	0.102492935	7.17394178	0.059673694	0.102492935	0.060321124	0.071642317
0.88	0.188	1.8597	0.101202	0.02	0.059	0.095	0.06084286	0.104501044	7.185793683	0.06084286	0.104501044	0.061476738	0.07301482
0.88	0.185	1.8528	0.099938	0.02	0.059	0.095	0.059363099	0.10195947	7.17075509	0.059363099	0.10195947	0.060014092	0.071277662
0.88	0.096	1.3772	0.069707	0.02	0.059	0.095	0.024205391	0.041574125	6.752875837	0.024205391	0.041574125	0.024044386	0.028557086
0.88	0.087	1.2948	0.067192	0.02	0.059	0.095	0.021405318	0.036764841	6.711647748	0.021405318	0.036764841	0.021109724	0.025071641
0.88	0.113	1.4048	0.080438	0.02	0.059	0.095	0.031345784	0.053838152	6.915979844	0.031345784	0.053838152	0.030828077	0.036613955
0.88	0.254	1.587	0.16005	0.02	0.059	0.095	0.11146272	0.191443508	7.756262993	0.11146272	0.191443508	0.104971769	0.124673088
0.88	0.183	1.4636	0.125034	0.02	0.059	0.095	0.068117956	0.116996432	7.443568275	0.068117956	0.116996432	0.064739069	0.076889432
0.88	0.19	1.4748	0.128831	0.02	0.059	0.095	0.072148168	0.123918548	7.480772946	0.072148168	0.123918548	0.0684621124	0.081317911
0.88	0.187	1.418	0.131876	0.02	0.059	0.095	0.072123465	0.123876119	7.509954238	0.072123465	0.123876119	0.067832247	0.080563144
0.88	0.193	1.4804	0.13037	0.02	0.059	0.095	0.073869902	0.126875723	7.495594781	0.073869902	0.126875723	0.070069637	0.083220451
0.88	0.206	1.454	0.141678	0.02	0.059	0.095	0.083341342	0.143143455	7.600232248	0.083341342	0.143143455	0.078196484	0.092872562
0.88	0.207	1.455	0.142268	0.02	0.059	0.095	0.083978215	0.144237321	7.605497363	0.083978215	0.144237321	0.07877275	0.093556982
0.88	0.18	1.405	0.128114	0.02	0.059	0.095	0.068097006	0.116960449	7.4738164	0.068097006	0.116960449	0.06416967	0.076150572
0.88	0.193	1.4814	0.130282	0.02	0.059	0.095	0.073836655	0.12681862	7.494751243	0.073836655	0.12681862	0.070050713	0.083197976
0.88	0.181	1.46	0.123973	0.02	0.059	0.095	0.066991615	0.115061877	7.432997976	0.066991615	0.115061877	0.063692325	0.075646233
0.88	0.178	1.4538	0.122438	0.02	0.059	0.095	0.065336363	0.112218888	7.417580775	0.065336363	0.112218888	0.062145351	0.073808919
0.88	0.251	1.583	0.15856	0.02	0.059	0.095	0.109461229	0.188005834	7.744175666	0.109461229	0.188005834	0.103132192	0.122488255
0.88	0.219	1.4768	0.148294	0.02	0.059	0.095	0.091337782	0.156877792	7.658260468	0.091337782	0.156877792	0.085563742	0.101622522
0.88	0.23	1.498	0.153538	0.02	0.059	0.095	0.098174021	0.168619418	7.702748744	0.098174021	0.168619418	0.091895239	0.109142327
0.88	0.304	1.7172	0.177032	0.02	0.059	0.095	0.142681208	0.245063023	7.887726535	0.142681208	0.245063023	0.134937184	0.160262475
0.88	0.161	1.4828	0.108578	0.02	0.059	0.095	0.05454808	0.093689404	7.270544627	0.05454808	0.093689404	0.052650672	0.062532259
0.88	0.214	1.5704	0.136271	0.02	0.059	0.095	0.084360826	0.144894477	7.551101521	0.084360826	0.144894477	0.080507548	0.095617371
0.88	0.135	0.13198	1.022882	0.02	0.059	0.095	0.204021338	0.350418155	10.56608262	0.204021338	0.350418155	0.105029577	0.124741746
0.88	0.138	1.3264	0.104041	0.02	0.059	0.095	0.045443684	0.07805209	7.219001913	0.045443684	0.07805209	0.043197623	0.051305042
0.88	0.179	1.4022	0.127657	0.02	0.059	0.095	0.067557432	0.116033701	7.469363116	0.067557432	0.116033701	0.063608284	0.075546419
0.88	0.175	1.3946	0.125484	0.02	0.059	0.095	0.065296269	0.112150025	7.448025005	0.065296269	0.112150025	0.061520355	0.073066623
0.88	0.181	1.4066	0.128679	0.02	0.059	0.095	0.068676572	0.117955886	7.479301749	0.068676572	0.117955886	0.064648731	0.076782138
0.88	0.19	1.423	0.133521	0.02	0.059	0.095	0.073888604	0.126907845	7.525485296	0.073888604	0.126907845	0.069454006	0.082489278
0.88	0.41458	2.227	0.186161	0.02	0.059	0.095	0.201214138	0.345596632	7.954100666	0.201214138	0.345596632	0.198111503	0.23529348
0.88	0.36464	2.112	0.172652	0.02	0.059	0.095	0.168307175	0.289077066	7.854854179	0.168307175	0.289077066	0.165361666	0.196397086
0.88	0.87329	3.05	0.286325	0.02	0.059	0.095	0.564749227	0.969988651	8.545802191	0.564749227	0.969988651	0.563926123	0.669764946
0.88	0.81755	2.95	0.277136	0.02	0.059	0.095	0.517329511	0.888542614	8.499468706	0.517329511	0.888542614	0.515176533	0.611865932
0.88	0.73045	2.719	0.268647	0.02	0.059	0.095	0.452726667	0.777583586	8.455512625	0.452726667	0.777583586	0.445824583	0.529497864
0.88	0.62361	2.465	0.252986	0.02	0.059	0.095	0.371337288	0.637792737	8.371290619	0.371337288	0.637792737	0.361552476	0.429409393
0.88	0.63581	2.675	0.237686	0.02	0.059	0.095	0.363179332	0.623780987	8.284703867	0.363179332	0.623780987	0.360748275	0.428454258
0.88	0.65961	2.699	0.244391	0.02	0.059	0.095	0.383826411	0.65924351	8.323202337	0.383826411	0.65924351	0.380853113	0.452332414
0.88	1.67806	4.248	0.395024	0.02	0.059	0.095	1.344871724	2.309893041	9.016684858	1.344871724	2.309893041	1.379901923	1.638884774
0.88	1.7489	4.292	0.407479	0.02	0.059	0.095	1.430956878	2.45774915	9.063458255	1.430956878	2.45774915	1.466578364	1.741828828
0.88	1.95909	4.675	0.419057	0.02	0.059	0.095	1.633155842	2.805037275	9.105878618	1.633155842	2.805037275	1.69429393	2.012282523
0.88	2.06942	4.842	0.42739	0.02	0.059	0.095	1.747924243	3.002158477	9.135809552	1.747924243	3.002158477	1.821041524	2.162818368

Figure A12-1. Observed and modeled rating curves and streamflow from Site 12, West Run Watershed, Morgantown, West Virginia, U.S.A.

Table A12-3. Polynomial rating equations and R^2 values for observed and modeled rating curves at Site 12, West Run Watershed, Morgantown, WV, U.S.A.

	R² Value	Polynomial Equation
Observed Curve	0.99	$y = 0.8172x^2 + 0.7243x - 0.1282$
Manning's Curve (Obs Slope)	0.70	$y = 2.8829x^2 - 0.5451x + 0.0722$
Manning's Curve (Calc Slope)	0.70	$y = 4.9515x^2 - 0.9362x + 0.1239$
Chezy's Curve (Obs Slope)	0.70	$y = 2.8829x^2 - 0.5451x + 0.0722$
Chezy's Curve (Calc Slope)	0.70	$y = 4.9515x^2 - 0.9362x + 0.1239$
Dingman and Sharma's Curve (Obs Slope)	0.69	$y = 2.9506x^2 - 0.5409x + 0.0625$
Dingman and Sharma's Curve (Calc Slope)	0.69	$y = 3.5044x^2 - 0.6425x + 0.0742$

Table A12-4. Descriptive statistics for observed and modeled streamflow used to generate the rating curves for Site 12, West Run Watershed, Morgantown, WV, U.S.A.

	Sample Size	Mean (m³/s)	St. Dev.	SE of Mean
Observed	46	0.18	0.266	0.039
Manning's Curve (Obs Slope)	46	0.257	0.423	0.062
Manning's Curve (Calc Slope)	46	0.441	0.727	0.107
Chezy's Curve (Obs Slope)	46	0.257	0.423	0.062
Chezy's Curve (Calc Slope)	46	0.441	0.727	0.107
Dingman and Sharma's Curve (Obs Slope)	46	0.256	0.439	0.065
Dingman and Sharma's Curve (Calc Slope)	46	0.305	0.521	0.077

Table A12-5. P-values of the statistical analyses (post-hoc ANOVA) for observed and modeled rating curves at Site 12, West Run Watershed, Morgantown, WV, U.S.A.

	Observed Curve	Rating Equation Curve	Manning's Curve (Obs Slope)	Manning's Curve (Calc Slope)	Chezy's Curve (Obs Slope)	Chezy's Curve (Calc Slope)	Dingman and Sharma's Curve (Obs Slope)	Dingman and Sharma's Curve (Calc Slope)
Observed Curve	-	1	1	0.20	1	0.20	1	0.93
Rating Equation Curve	-	-	1	0.20	1	0.20	1	0.93
Manning's Curve (Obs Slope)	-	-	-	0.65	1	0.65	1	1
Manning's Curve (Calc Slope)	-	-	-	-	0.65	1	0.65	0.90
Chezy's Curve (Obs Slope)	-	-	-	-	-	0.65	1	1
Chezy's Curve (Calc Slope)	-	-	-	-	-	-	0.65	0.90
Dingman and Sharma's Curve (Obs Slope)	-	-	-	-	-	-	-	1
Dingman and Sharma's Curve (Calc Slope)	-	-	-	-	-	-	-	-

Figure A12-2. Box and whisker plots for the results of the statistical analyses (post-hoc ANOVA) of observed and modeled rating curves at Site 12, West Run Watershed, Morgantown, WV, U.S.A.

Figure A12-3. Cross-sectional profile of WRW Site 12, West Run Watershed, Morgantown, WV, USA (Figure 2). Channel Width of zero (0) represents the left bank facing downstream.

Figure A12-4. Plan view profile of WRW Site 12, West Run Watershed, Morgantown, WV, U.S.A. (Figure 2). Showing the positioning of stilling well in relation to where the streamflow was measured. Along with the channel width at the stilling well, point where cross-sections were performed, and 15.5m upstream and downstream from the stilling well.

Figure A12-5. Photographs showing channel characteristics at Site #12, West Run Watershed, Morgantown, WV, U.S.A. Photo 1 was taken looking upstream in the channel. Photo 2 was taken from the left bank looking downstream.

APPENDIX 13: Site 13

Table A13-1. Streamflow measurements and stage collected at Site 13, West Run Watershed, Morgantown, WV, U.S.A. (Figure 2).

Date	Mean Depth of Cross-Section (m)	Stage(PT in cm)	Barometric Pressure (in cm)	Pressure Corrected Stage (cm)	Stilling Well Offset (cm)	P-Corrected Stage + Offset (cm)	P-Corrected Stage + Offset (m)	SonTec Discharge (m3/s)	Rating Equation Discharge (m3/s)
9/21/2017	0.1826	103.67	88.10	15.57	7	22.57	0.2257	0.0331	0.0273
9/28/2017	0.1612	102.26	85.56	16.70	7	23.7	0.237	0.0250	0.0369
10/5/2017	0.1403	108.20	92.08	16.12	7	23.12	0.2312	0.0207	0.0318
10/5/2017	0.1605	108.30	92.22	16.08	7	23.08	0.2308	0.0208	0.0315
10/8/2017	0.1940	103.19	82.86	20.33	7	27.33	0.2733	0.0461	0.0756
10/9/2017	0.2345	104.54	78.43	26.11	7	33.11	0.3311	0.1227	0.1615
10/9/2017	0.2232	103.55	80.12	23.43	7	30.43	0.3043	0.0887	0.1180
10/9/2017	0.2010	103.38	81.00	22.38	7	29.38	0.2938	0.0748	0.1027
10/10/2017	0.1918	106.66	88.87	17.79	7	24.79	0.2479	0.0379	0.0473
10/11/2017	0.1824	102.56	83.11	19.45	7	26.45	0.2645	0.0526	0.0651
10/23/2017	0.1540	97.92	82.79	15.13	7	22.13	0.2213	0.0247	0.0238
10/23/2017	0.1845	94.47	76.28	18.19	7	25.19	0.2519	0.0458	0.0514
10/24/2017	0.2276	101.74	75.83	25.91	7	32.91	0.3291	0.1761	0.1581
10/24/2017	0.2108	99.82	75.94	23.88	7	30.88	0.3088	0.1475	0.1248
10/29/2017	0.3348	111.70	72.76	38.94	7	45.94	0.4594	0.3930	0.4591
10/29/2017	0.2995	111.19	72.47	38.72	7	45.72	0.4572	0.4266	0.4528
10/30/2017	0.2423	109.11	76.49	32.62	7	39.62	0.3962	0.2470	0.2941
11/3/2017	0.1484	105.96	88.07	17.89	7	24.89	0.2489	0.0670	0.0483
11/6/2017	0.3548	137.46	85.87	51.59	7	58.59	0.5859	0.8132	0.8967
11/7/2017	0.3278	120.14	87.83	32.31	7	39.31	0.3931	0.2888	0.2870
1/21/2018	0.1836	111.94	88.54	23.40	7.9	31.3375	0.313375	0.1671	0.1320
3/16/2018	0.1567	105.31	86.48	18.83	7.9	26.7675	0.267675	0.1000	0.0688
3/23/2018	0.1648	110.56	88.98	21.58	7.9	29.5175	0.295175	0.1442	0.1046
3/30/2018	0.4115	135.92	83.96	51.96	7.9	59.8975	0.598975	0.8180	0.9501
4/5/2018	0.2848	125.91	87.48	38.43	7.9	46.3675	0.463675	0.4426	0.4716
7/6/2018	0.2600	116.84	91.22	25.62	7.9	33.5575	0.335575	0.1452	0.1694
7/18/2018	0.1448	98.76	86.61	12.15	7.9	20.0875	0.200875	0.0212	0.0101
7/23/2018	0.1911	94.15	80.74	13.41	7.9	21.3475	0.213475	0.0480	0.0181
7/26/2018	0.2271	102.13	84.16	17.97	7.9	25.9075	0.259075	0.0621	0.0590
9/18/2018	0.3389	122.10	81.06	41.04	7.9	48.9775	0.489775	0.5045	0.5511
9/20/2018	0.2719	112.99	89.17	23.82	7.9	31.7575	0.317575	0.1599	0.1387
10/2/2018	0.3130	110.65	87.69	22.96	7.9	30.8975	0.308975	0.1346	0.1251
10/2/2018	0.3048	110.53	87.55	22.98	7.9	30.9175	0.309175	0.1252	0.1254
11/1/2018	0.2829	95.70	75.67	20.03	7.9	27.9675	0.279675	0.1005	0.0836
1/15/2019	0.2533	110.32	87.74	22.58	7.9	30.5175	0.305175	0.1089	0.1193
1/15/2019	0.2698	110.43	87.64	22.79	7.9	30.7275	0.307275	0.1005	0.1225
2/26/2019	0.3261	126.28	94.10	32.18	7.9	40.1175	0.401175	0.2875	0.3058
10/31/2019	0.3436	107.31	68.48	38.83	7.9	46.73	0.4673	0.4770	0.4823
1/4/2020	0.3753	120.86	73.76	47.10	7.9	55	0.55	0.7432	0.7580
1/4/2020	0.3676	120.37	73.47	46.90	7.9	54.8	0.548	0.6746	0.7506
1/4/2020	0.4338	116.98	71.88	45.10	7.9	53	0.53	0.7071	0.6857
4/9/2020	0.4170	1032.70	980.95	51.80	7.9	59.7	0.597	0.8740	0.9420
4/9/2020	0.4140	1032.30	980.70	51.60	7.9	59.5	0.595	0.9384	0.9337
4/9/2020	0.4180	1031.70	980.76	50.90	7.9	58.8	0.588	0.9231	0.9052
4/9/2020	0.4100	1030.90	980.95	49.90	7.9	57.8	0.578	0.9098	0.8652
4/9/2020	0.4040	1029.90	980.85	49.00	7.9	56.9	0.569	0.8939	0.8300
4/9/2020	0.3850	1029.50	980.83	48.70	7.9	56.6	0.566	0.8515	0.8184
4/9/2020	0.3950	1029.70	981.55	48.10	7.9	56	0.56	0.7990	0.7955
4/9/2020	0.3820	1029.20	981.87	47.30	7.9	55.2	0.552	0.8007	0.7654
4/9/2020	0.3920	1029.40	983.23	46.20	7.9	54.1	0.541	0.8113	0.7250
4/9/2020	0.3920	1028.10	983.18	44.90	7.9	52.8	0.528	0.7707	0.6787
4/9/2020	0.3770	1028.40	983.52	44.90	7.9	52.8	0.528	0.7634	0.6787
4/9/2020	0.4020	1029.10	984.10	45.00	7.9	52.9	0.529	0.7868	0.6822

Table A13-2. Modeled streamflow at Site 13, West Run Watershed, Morgantown, WV, U.S.A.

Cross-Section Area (m ²)	A (Cross Section area of flow)	P (Wetted Perimeter)	RH=A/P Hydraulic Radius (m)	Observed Slope (m)	Calculated Slope using ArcGIS (m)	Roughness Coefficient (n)	Manning Discharge (m ³ /s) (Obs Slope)	Manning Discharge (m ³ /s) (Calc Slope)	Chezy Coefficient (C)	Chezy Discharge (m ³ /s) (Obs Slope)	Chezy Discharge (m ³ /s) (Calc Slope)	Dingman & Sharma Discharge (m ³ /s) (Obs. Slope)	Dingman & Sharma Discharge (m ³ /s) (Calc Slope)
2.72	0.238	1.9665	0.120862	0.0075	0.008	0.064	0.078618	0.081196321	10.98672684	0.078618	0.081196321	0.070793065	0.071848251
2.72	0.256	2.0034	0.127638	0.0075	0.008	0.064	0.087715572	0.090592253	11.08707286	0.087715572	0.090592253	0.078835578	0.080010664
2.72	0.246	1.9846	0.124183	0.0075	0.008	0.064	0.083007883	0.085730173	11.03647664	0.083007883	0.085730173	0.074674654	0.075787696
2.72	0.246	1.9833	0.123943	0.0075	0.008	0.064	0.082686162	0.085397901	11.03291826	0.082686162	0.085397901	0.074390237	0.07549904
2.72	0.306	1.967	0.155567	0.0075	0.008	0.064	0.119770573	0.123698516	11.45881049	0.119770573	0.123698516	0.105334469	0.106904501
2.72	0.406	2.2678	0.178972	0.0075	0.008	0.064	0.174418876	0.180139041	11.72962589	0.174418876	0.180139041	0.155168474	0.157481293
2.72	0.363	2.2002	0.165029	0.0075	0.008	0.064	0.147826663	0.152674721	11.5721329	0.147826663	0.152674721	0.131822666	0.133787511
2.72	0.346	2.1721	0.159454	0.0075	0.008	0.064	0.13781099	0.142330578	11.50603705	0.13781099	0.142330578	0.123013203	0.124846741
2.72	0.273	2.0379	0.134011	0.0075	0.008	0.064	0.096775215	0.099949013	11.17746818	0.096775215	0.099949013	0.086838398	0.088132743
2.72	0.300	2.0885	0.143446	0.0075	0.008	0.064	0.111088687	0.114731903	11.30494147	0.111088687	0.114731903	0.099470284	0.10095291
2.72	0.231	1.9518	0.118172	0.0075	0.008	0.064	0.075159159	0.077624046	10.94559112	0.075159159	0.077624046	0.067733593	0.068743177
2.72	0.279	2.0503	0.136313	0.0075	0.008	0.064	0.100167994	0.10345306	11.20923922	0.100167994	0.10345306	0.089833891	0.091172884
2.72	0.403	2.2630	0.177943	0.0075	0.008	0.064	0.172383679	0.178037098	11.71836392	0.172383679	0.178037098	0.15338415	0.155670373
2.72	0.370	2.2120	0.167397	0.0075	0.008	0.064	0.152188882	0.157180002	11.5996434	0.152188882	0.157180002	0.135656838	0.137678832
2.72	0.611	2.5056	0.243701	0.0075	0.008	0.064	0.322368698	0.332940959	12.34893507	0.322368698	0.332940959	0.283463214	0.287688294
2.72	0.607	2.5027	0.242579	0.0075	0.008	0.064	0.319530726	0.330009915	12.33944149	0.319530726	0.330009915	0.281033211	0.285222071
2.72	0.510	2.4061	0.211856	0.0075	0.008	0.064	0.245136207	0.253175586	12.06406446	0.245136207	0.253175586	0.216872825	0.220105361
2.72	0.275	2.0410	0.134588	0.0075	0.008	0.064	0.097620018	0.100821521	11.1854779	0.097620018	0.100821521	0.087584352	0.088889816
2.72	0.812	2.6014	0.312327	0.0075	0.008	0.064	0.506099027	0.522696828	12.87028523	0.506099027	0.522696828	0.437628687	0.444151636
2.72	0.729	2.8806	0.253072	0.0075	0.008	0.064	0.394676469	0.407620104	12.42684233	0.394676469	0.407620104	0.354266159	0.359546572
2.72	0.378	2.2238	0.169792	0.0075	0.008	0.064	0.15666651	0.161804476	11.6271442	0.15666651	0.161804476	0.13959068	0.141671309
2.72	0.305	2.0979	0.145218	0.0075	0.008	0.064	0.113895579	0.117630848	11.32809097	0.113895579	0.117630848	0.101945711	0.103465234
2.72	0.349	2.1758	0.160188	0.0075	0.008	0.064	0.13910954	0.143671715	11.51485176	0.13910954	0.143671715	0.124155839	0.126006408
2.72	0.833	2.6034	0.320095	0.0075	0.008	0.064	0.527668192	0.544973366	12.923093309	0.527668192	0.544973366	0.455293056	0.460792996
2.72	0.121	1.891	0.063987	0.0075	0.008	0.064	0.026193805	0.027052845	9.881791044	0.026193805	0.027052845	0.024865502	0.025236127
2.72	0.575	2.7302	0.210607	0.0075	0.008	0.064	0.275423351	0.284456013	12.05217946	0.275423351	0.284456013	0.249190903	0.252905147
2.72	0.165	1.4326	0.115175	0.0075	0.008	0.064	0.052853522	0.054586883	10.89882951	0.052853522	0.054586883	0.045258975	0.04593357
2.72	0.248	1.6774	0.147848	0.0075	0.008	0.064	0.093830861	0.096908096	11.36202829	0.093830861	0.096908096	0.080662242	0.08186453
2.72	0.26	1.5972	0.162785	0.0075	0.008	0.064	0.104889827	0.108329748	11.54575578	0.104889827	0.108329748	0.088605729	0.089926417
2.72	0.878	3.2688	0.2686	0.0075	0.008	0.064	0.494594502	0.510815006	12.55078973	0.494594502	0.510815006	0.451246642	0.45797257
2.72	0.497	2.3726	0.209475	0.0075	0.008	0.064	0.23720743	0.24498678	12.04135434	0.23720743	0.24498678	0.209571025	0.212694726
2.72	0.453	2.074	0.218419	0.0075	0.008	0.064	0.222318273	0.229609325	12.12555431	0.222318273	0.229609325	0.191148731	0.193997844
2.72	0.418	1.9816	0.210941	0.0075	0.008	0.064	0.200432033	0.207005314	12.05535695	0.200432033	0.207005314	0.17153642	0.174093207
2.72	0.345	1.7848	0.193299	0.0075	0.008	0.064	0.156071203	0.161189645	11.88114462	0.156071203	0.161189645	0.132253162	0.134224423
2.72	0.483	2.4116	0.200282	0.0075	0.008	0.064	0.223730757	0.231068132	11.95162621	0.223730757	0.231068132	0.199057789	0.202024788
2.72	0.514	2.4444	0.210277	0.0075	0.008	0.064	0.245946704	0.254012663	12.049023	0.245946704	0.254012663	0.218337597	0.221591965
2.72	0.746	2.9382	0.253897	0.0075	0.008	0.064	0.404757092	0.418031327	12.43358225	0.404757092	0.418031327	0.364450108	0.369882315
2.72	0.759	2.8972	0.261977	0.0075	0.008	0.064	0.420501904	0.434292499	12.4986731	0.420501904	0.434292499	0.376600916	0.382214233
2.72	1.001	3.4176	0.292896	0.0075	0.008	0.064	0.597392775	0.616984605	12.73323733	0.597392775	0.616984605	0.54481212	0.552932661
2.72	0.952	3.3262	0.286212	0.0075	0.008	0.064	0.559474116	0.577822383	12.68434729	0.559474116	0.577822383	0.508942859	0.516528761
2.72	0.959	3.0776	0.311606	0.0075	0.008	0.064	0.596449329	0.616010218	12.86533497	0.596449329	0.616010218	0.531090153	0.539006165
2.72	1.3316	4.034	0.330094	0.0075	0.008	0.064	0.860629786	0.888854621	12.98951716	0.860629786	0.888854621	0.798726434	0.810631622
2.72	1.29309	3.952	0.327199	0.0075	0.008	0.064	0.83084617	0.858094235	12.97045851	0.83084617	0.858094235	0.768984708	0.780446589
2.72	1.30587	3.96	0.329765	0.0075	0.008	0.064	0.843439188	0.871100247	12.98735821	0.843439188	0.871100247	0.78034201	0.791973175
2.72	1.26406	3.906	0.32362	0.0075	0.008	0.064	0.806260369	0.832702128	12.94670545	0.806260369	0.832702128	0.745487092	0.756598736
2.72	1.23155	3.856	0.319385	0.0075	0.008	0.064	0.778656754	0.804193238	12.91831479	0.778656754	0.804193238	0.71924808	0.729968627
2.72	1.15838	3.78	0.30645	0.0075	0.008	0.064	0.712483059	0.735849339	12.82960349	0.712483059	0.735849339	0.658405472	0.668219147
2.72	1.17406	3.762	0.312084	0.0075	0.008	0.064	0.730951593	0.754923559	12.868619	0.730951593	0.754923559	0.673763937	0.683806533
2.72	1.12006	3.698	0.302883	0.0075	0.008	0.064	0.683557206	0.705974847	12.80459233	0.683557206	0.705974847	0.629973429	0.639363318
2.72	1.11135	3.619	0.307088	0.0075	0.008	0.064	0.684504581	0.706953291	12.83405032	0.684504581	0.706953291	0.627683061	0.637038812
2.72	1.07535	3.527	0.304891	0.0075	0.008	0.064	0.659168963	0.680786778	12.81870312	0.659168963	0.680786778	0.602168679	0.611144132
2.72	1.03471	3.497	0.295885	0.0075	0.008	0.064	0.62170541	0.642094587	12.75480613	0.62170541	0.642094587	0.568700915	0.577177524
2.72	1.08769	3.509	0.309972	0.0075	0.008	0.064	0.674119627	0.696227757	12.85405994	0.674119627	0.696227757	0.614329938	0.623488657

Figure A13-1. Observed and modeled rating curves and streamflow from Site 13, West Run Watershed, Morgantown, West Virginia, U.S.A.

Table A13-3. Polynomial rating equations and R^2 values for observed and modeled rating curves at Site 13, West Run Watershed, Morgantown, WV, U.S.A.

	R² Value	Polynomial Equation
Observed Curve	0.98	$y = 4.4741x^2 - 1.2173x + 0.0741$
Manning's Curve (Obs Slope)	0.88	$y = 3.1634x^2 - 0.7756x + 0.1051$
Manning's Curve (Calc Slope)	0.88	$y = 3.2671x^2 - 0.801x + 0.1086$
Chezy's Curve (Obs Slope)	0.88	$y = 3.1634x^2 - 0.7756x + 0.1051$
Chezy's Curve (Calc Slope)	0.88	$y = 3.2671x^2 - 0.801x + 0.1086$
Dingman and Sharma's Curve (Obs Slope)	0.88	$y = 3.047x^2 - 0.8263x + 0.1122$
Dingman and Sharma's Curve (Calc Slope)	0.88	$y = 3.0924x^2 - 0.8387x + 0.1139$

Table A13-4. Descriptive statistics for observed and modeled streamflow used to generate the rating curves for Site 13, West Run Watershed, Morgantown, WV, U.S.A.

	Sample Size	Mean (m³/s)	St. Dev.	SE of Mean
Observed	53	0.365	0.336	0.046
Manning's Curve (Obs Slope)	53	0.344	0.263	0.036
Manning's Curve (Calc Slope)	53	0.355	0.271	0.037
Chezy's Curve (Obs Slope)	53	0.344	0.263	0.036
Chezy's Curve (Calc Slope)	53	0.355	0.271	0.037
Dingman and Sharma's Curve (Obs Slope)	53	0.311	0.243	0.033
Dingman and Sharma's Curve (Calc Slope)	53	0.316	0.247	0.034

Table A13-5. P-values of the statistical analyses (post-hoc ANOVA) for observed and modeled rating curves at Site 13, West Run Watershed, Morgantown, WV, U.S.A.

	Observed Curve	Rating Equation Curve	Manning's Curve (Obs Slope)	Manning's Curve (Calc Slope)	Chezy's Curve (Obs Slope)	Chezy's Curve (Calc Slope)	Dingman and Sharma's Curve (Obs Slope)	Dingman and Sharma's Curve (Calc Slope)
Observed Curve	-	1	1	1	1	1	0.98	0.99
Rating Equation Curve	-	-	1	1	1	1	0.98	0.99
Manning's Curve (Obs Slope)	-	-	-	1	1	1	1	1
Manning's Curve (Calc Slope)	-	-	-	-	1	1	0.99	1
Chezy's Curve (Obs Slope)	-	-	-	-	-	1	1	1
Chezy's Curve (Calc Slope)	-	-	-	-	-	-	0.99	1
Dingman and Sharma's Curve (Obs Slope)	-	-	-	-	-	-	-	1
Dingman and Sharma's Curve (Calc Slope)	-	-	-	-	-	-	-	-

Figure A13-2. Box and whisker plots for the results of the statistical analyses (post-hoc ANOVA) of observed and modeled rating curves at Site 13, West Run Watershed, Morgantown, WV, U.S.A.

Figure A13-3. Cross-sectional profile of WRW Site 13, West Run Watershed, Morgantown, WV, USA (Figure 2). Channel Width of zero (0) represents the left bank facing downstream.

Figure A13-4. Plan view profile of WRW Site 13, West Run Watershed, Morgantown, WV, U.S.A. (Figure 2). Showing the positioning of stilling well in relation to where the streamflow was measured. Along with the channel width at the stilling well, point where cross-sections were performed, and 6.0m upstream and downstream from the stilling well.

Figure A13-5. Photographs showing channel characteristics at Site #13, West Run Watershed, Morgantown, WV, U.S.A. Photo 1 was taken looking upstream in the channel. Photo 2 was taken from the right bank looking downstream.

APPENDIX 14: Site 14

Table A14-1. Streamflow measurements and stage collected at Site 14, West Run Watershed, Morgantown, WV, U.S.A. (Figure 2).

Date	Mean Depth of Cross-Section (m)	Stage(PT in cm)	Barometric Pressure (in cm)	Pressure Corrected Stage (cm)	Stilling Well Offset (cm)	P-Corrected Stage + Offset (cm)	P-Corrected Stage + Offset (m)	SonTec Discharge (m3/s)	Rating Equation Discharge (m3/s)
10/9/2017	0.0988	99.12	79.4	19.72	4	23.72	0.2372	0.0135	0.0253
10/9/2017	0.0787	99.44	80.88	18.56	4	22.56	0.2256	0.0146	0.0209
10/9/2017	0.0803	98.93	80.83	18.1	4	22.1	0.221	0.0076	0.0199
10/24/2017	0.1134	98.3	75.47	22.83	4	26.83	0.2683	0.0366	0.0512
10/24/2017	0.1053	98.3	76.43	21.87	4	25.87	0.2587	0.0353	0.0410
10/29/2017	0.1372	100.48	72.13	28.35	4	32.35	0.3235	0.0958	0.1473
10/30/2017	0.1119	102.9	76.96	25.94	4	29.94	0.2994	0.0613	0.0974
11/3/2017	0.0832	107	88.2	18.8	4	22.8	0.228	0.0160	0.0215
11/7/2017	0.1836	114.78	87.28	27.5	4	31.5	0.315	0.1158	0.1283
1/21/2018	0.1254	111.87	88.21	23.66	4.1	27.76	0.2776	0.0601	0.0629
3/23/2018	0.1174	106.41	88.66	17.75	4.1	21.85	0.2185	0.0396	0.0195
4/5/2018	0.1549	117.05	87.52	29.53	4.1	33.63	0.3363	0.1332	0.1787
9/20/2018	0.1097	108.51	89.35	19.16	4.1	23.26	0.2326	0.0386	0.0232
9/20/2018	0.0963	108.54	89.33	19.21	4.1	23.31	0.2331	0.0332	0.0234
10/2/2018	0.1042	104.88	88.13	16.75	4.1	20.85	0.2085	0.0266	0.0195
10/2/2018	0.1049	104.65	87.99	16.66	4.1	20.76	0.2076	0.0258	0.0196
10/16/2018	0.1116	108.76	90.62	18.14	4.1	22.24	0.2224	0.0298	0.0201
10/16/2018	0.1018	108.46	90.18	18.28	4.1	22.38	0.2238	0.0345	0.0204
1/15/2019	0.1167	107.57	87.52	20.05	4.1	24.15	0.2415	0.0337	0.0277
1/15/2019	0.1061	107.58	87.48	20.1	4.1	24.2	0.242	0.0356	0.0280
2/26/2019	0.1259	117.6	94	23.6	4.1	27.7	0.277	0.0715	0.0621
2/26/2019	0.1219	117.39	93.74	23.65	4.1	27.75	0.2775	0.0794	0.0628
2/13/2020	0.2531	1036.1	990.03	46.1	4.1	50.2	0.502	0.8412	0.8967
2/13/2020	0.2493	1036.4	990.11	46.3	4.1	50.4	0.504	0.9001	0.9089
2/13/2020	0.2534	1037.7	990.20	47.5	4.1	51.6	0.516	0.8418	0.9838
9/1/2021	0.2880	1032.5	988.39	44.1	4.1	48.2	0.482	0.8089	0.7794
9/1/2021	0.2890	1033.2	988.44	44.8	4.1	48.9	0.489	0.8972	0.8195
9/1/2021	0.3060	1032.5	988.39	44.1	4.1	48.2	0.482	0.8232	0.7794
9/1/2021	0.3060	1033.2	988.33	44.9	4.1	49	0.49	0.7790	0.8253
9/1/2021	0.2880	1031.6	988.29	43.3	4.1	47.4	0.474	0.7860	0.7348
9/1/2021	0.2860	1032	988.26	43.7	4.1	47.8	0.478	0.7664	0.7569
9/1/2021	0.2850	1030.9	988.26	42.6	4.1	46.7	0.467	0.7721	0.6969
9/1/2021	0.3020	1030.7	988.28	42.4	4.1	46.5	0.465	0.7751	0.6863
9/1/2021	0.3010	1029.3	988.44	40.9	4.1	45	0.45	0.5700	0.6092

Table A14-2. Modeled streamflow at Site 14, West Run Watershed, Morgantown, WV, U.S.A.

Cross-Section Area (m ²)	A (Cross Section area of flow)	P (Wetted Perimeter)	RH=A/P Hydraulic Radius (m)	Observed Slope (m)	Calculated Slope using ArcGIS (m)	Roughness Coefficient (n)	Manning Discharge (m ³ /s) (Obs Slope)	Manning Discharge (m ³ /s) (Calc Slope)	Chezy Coefficient (C)	Chezy Discharge (m ³ /s) (Obs Slope)	Chezy Discharge (m ³ /s) (Calc Slope)	Dingman & Sharma Discharge (m ³ /s) (Obs. Slope)	Dingman & Sharma Discharge (m ³ /s) (Calc Slope)
0.83	0.256	2.0040	0.127757	0.04	0.027	0.09	0.144319006	0.118570162	7.885358322	0.144319006	0.118570162	0.10878974	0.102115419
0.83	0.238	1.9661	0.120801	0.04	0.027	0.09	0.128979722	0.105967655	7.812128341	0.128979722	0.105967655	0.097416028	0.091439491
0.83	0.230	1.9508	0.117988	0.04	0.027	0.09	0.123045002	0.101091785	7.781504722	0.123045002	0.101091785	0.093012962	0.087306557
0.83	0.306	2.0998	0.145565	0.04	0.027	0.09	0.1879556	0.154421283	8.058741423	0.1879556	0.154421283	0.141097243	0.132440835
0.83	0.290	2.0711	0.140184	0.04	0.027	0.09	0.174107187	0.14304365	8.008303451	0.174107187	0.14304365	0.130851673	0.122823837
0.83	0.394	2.2493	0.175054	0.04	0.027	0.09	0.273808396	0.224956553	8.310354816	0.273808396	0.224956553	0.204443436	0.191900698
0.83	0.355	2.1872	0.162436	0.04	0.027	0.09	0.235044452	0.193108722	8.207382234	0.235044452	0.193108722	0.175880641	0.165090249
0.83	0.241	1.9741	0.122256	0.04	0.027	0.09	0.132109856	0.108539323	7.827733246	0.132109856	0.108539323	0.099737718	0.093618744
0.83	0.154	1.2072	0.127568	0.04	0.027	0.09	0.086723315	0.071250474	7.883415306	0.086723315	0.071250474	0.059893559	0.05621905
0.83	0.320	2.1268	0.150694	0.04	0.027	0.09	0.201684088	0.165700386	8.105382694	0.201684088	0.165700386	0.151247107	0.141967998
0.83	0.226	1.9424	0.116445	0.04	0.027	0.09	0.119855718	0.09847152	7.764449225	0.119855718	0.09847152	0.09064613	0.085084931
0.83	0.414	2.2802	0.181639	0.04	0.027	0.09	0.295190399	0.24252366	8.361653393	0.295190399	0.24252366	0.220167112	0.206659716
0.83	0.109	1.2102	0.090068	0.04	0.027	0.09	0.048669873	0.039986381	7.439076911	0.048669873	0.039986381	0.034741674	0.03261025
0.83	0.103	1.2558	0.082019	0.04	0.027	0.09	0.043208502	0.035499407	7.323920389	0.043208502	0.035499407	0.031314572	0.029393403
0.83	0.111	1.2754	0.087032	0.04	0.027	0.09	0.048442682	0.039799724	7.396681497	0.048442682	0.039799724	0.035007105	0.032859396
0.83	0.12	1.3528	0.088705	0.04	0.027	0.09	0.053039632	0.043576504	7.420196947	0.053039632	0.043576504	0.038652749	0.036281377
0.83	0.119	1.2902	0.092234	0.04	0.027	0.09	0.053983503	0.044351974	7.468599041	0.053983503	0.044351974	0.038877137	0.036491999
0.83	0.109	1.2708	0.085773	0.04	0.027	0.09	0.047110044	0.038704851	7.378742801	0.047110044	0.038704851	0.034069261	0.03197909
0.83	0.116	1.2242	0.094756	0.04	0.027	0.09	0.053577513	0.044018419	7.502253928	0.053577513	0.044018419	0.038139341	0.035799468
0.83	0.113	1.2792	0.088336	0.04	0.027	0.09	0.049807253	0.040920834	7.415051232	0.049807253	0.040920834	0.035961577	0.033755311
0.83	0.182	1.6998	0.107071	0.04	0.027	0.09	0.091195747	0.074924951	7.656608087	0.091195747	0.074924951	0.067928947	0.063761462
0.83	0.167	1.6158	0.103354	0.04	0.027	0.09	0.081731575	0.067149341	7.611652772	0.081731575	0.067149341	0.060547984	0.056833326
0.83	0.783	2.6402	0.296568	0.04	0.027	0.09	0.773806794	0.635747154	9.073572488	0.773806794	0.635747154	0.565397964	0.530710431
0.83	0.7714	2.6326	0.293018	0.04	0.027	0.09	0.756246932	0.621320256	9.055378688	0.756246932	0.621320256	0.552915333	0.518993617
0.83	0.76995	2.6028	0.295816	0.04	0.027	0.09	0.759622511	0.624093577	9.0697318	0.759622511	0.624093577	0.553797447	0.519821613
0.83	0.750776	2.557	0.293616	0.04	0.027	0.09	0.737027717	0.605530059	9.058453331	0.737027717	0.605530059	0.536051854	0.503164724
0.83	0.75414	2.559	0.294701	0.04	0.027	0.09	0.742152993	0.609740903	9.064024227	0.742152993	0.609740903	0.539666067	0.506557202
0.83	0.802976	2.593	0.30967	0.04	0.027	0.09	0.81675092	0.671029354	9.139184682	0.81675092	0.671029354	0.59251237	0.55616135
0.83	0.802976	2.593	0.30967	0.04	0.027	0.09	0.81675092	0.671029354	9.139184682	0.81675092	0.671029354	0.59251237	0.55616135
0.83	0.749935	2.557	0.293287	0.04	0.027	0.09	0.735652231	0.604399982	9.056761366	0.735652231	0.604399982	0.535107615	0.502278414
0.83	0.72263	2.553	0.283051	0.04	0.027	0.09	0.692276763	0.568763399	9.003298224	0.692276763	0.568763399	0.50509814	0.474110039
0.83	0.719266	2.551	0.281954	0.04	0.027	0.09	0.687272916	0.564652319	8.997474388	0.687272916	0.564652319	0.501561617	0.470790485
0.83	0.719266	2.585	0.278246	0.04	0.027	0.09	0.68123325	0.559690227	8.977641748	0.68123325	0.559690227	0.498912355	0.468303756
0.83	0.679905	2.583	0.263223	0.04	0.027	0.09	0.62056166	0.50984343	8.894976302	0.62056166	0.50984343	0.456786258	0.428762124

Figure A14-1. Observed and modeled rating curves and streamflow from Site 14, West Run Watershed, Morgantown, West Virginia, U.S.A.

Table A14-3. Polynomial rating equations and R^2 values for observed and modeled rating curves at Site 14, West Run Watershed, Morgantown, WV, U.S.A.

	R² Value	Polynomial Equation
Observed Curve	0.99	$y = 10.518x^2 - 4.4843x + 0.4972$
Manning's Curve (Obs Slope)	0.91	$y = -1.617x^2 + 2.6303x - 0.4351$
Manning's Curve (Calc Slope)	0.91	$y = -1.3285x^2 + 2.161x - 0.3575$
Chezy's Curve (Obs Slope)	0.91	$y = -1.617x^2 + 2.6303x - 0.4351$
Chezy's Curve (Calc Slope)	0.91	$y = -1.3285x^2 + 2.161x - 0.3575$
Dingman and Sharma's Curve (Obs Slope)	0.91	$y = -1.1147x^2 + 1.9015x - 0.3156$
Dingman and Sharma's Curve (Calc Slope)	0.91	$y = -1.0463x^2 + 1.7848x - 0.2962$

Table A14-4. Descriptive statistics for observed and modeled streamflow used to generate the rating curves for Site 14, West Run Watershed, Morgantown, WV, U.S.A.

	Sample Size	Mean (m³/s)	St. Dev.	SE of Mean
Observed	34	0.312	0.368	0.063
Manning's Curve (Obs Slope)	34	0.243	0.179	0.031
Manning's Curve (Calc Slope)	34	0.199	0.147	0.025
Chezy's Curve (Obs Slope)	34	0.243	0.179	0.031
Chezy's Curve (Calc Slope)	34	0.199	0.147	0.025
Dingman and Sharma's Curve (Obs Slope)	34	0.181	0.134	0.023
Dingman and Sharma's Curve (Calc Slope)	34	0.17	0.126	0.022

Table A14-5. P-values of the statistical analyses (post-hoc ANOVA) for observed and modeled rating curves at Site 14, West Run Watershed, Morgantown, WV, U.S.A.

	Observed Curve	Rating Equation Curve	Manning's Curve (Obs Slope)	Manning's Curve (Calc Slope)	Chezy's Curve (Obs Slope)	Chezy's Curve (Calc Slope)	Dingman and Sharma's Curve (Obs Slope)	Dingman and Sharma's Curve (Calc Slope)
Observed Curve	-	1	0.91	0.45	0.91	0.45	0.26	0.17
Rating Equation Curve	-	-	0.91	0.45	0.91	0.45	0.26	0.17
Manning's Curve (Obs Slope)	-	-	-	0.99	1	0.99	0.95	0.89
Manning's Curve (Calc Slope)	-	-	-	-	0.99	1	1	1
Chezy's Curve (Obs Slope)	-	-	-	-	-	0.99	0.95	0.89
Chezy's Curve (Calc Slope)	-	-	-	-	-	-	1	1
Dingman and Sharma's Curve (Obs Slope)	-	-	-	-	-	-	-	1
Dingman and Sharma's Curve (Calc Slope)	-	-	-	-	-	-	-	-

Figure A14-2. Box and whisker plots for the results of the statistical analyses (post-hoc ANOVA) of observed and modeled rating curves at Site 14, West Run Watershed, Morgantown, WV, U.S.A.

Figure A14-3. Cross-sectional profile of WRW Site 14, plotting the stream channel's shape, water surface, and bankfull. The profile is created with a Channel Width of 0= Left Bank facing downstream.

Figure A14-5. Photographs showing channel characteristics at Site #14, West Run Watershed, Morgantown, WV, U.S.A. Photo 1 was taken looking upstream in the channel. Photo 2 was taken from the right bank looking upstream.

APPENDIX 15: Site 15

Table A15-1. Streamflow measurements and stage collected at Site 15, West Run Watershed, Morgantown, WV, U.S.A. (Figure 2).

Date	Mean Depth of Cross-Section (m)	Stage(PT in cm)	Barometric Pressure (in cm)	Pressure Corrected Stage (cm)	Stilling Well Offset (cm)	P-Corrected Stage + Offset (cm)	P-Corrected Stage + Offset (m)	SonTec Discharge (m3/s)	Rating Equation Discharge (m3/s)
9/21/2017	0.0733	132.36	87.33	45.03	10	55.03	0.5503	0.0016	0.0200
9/28/2017	0.0609	129.94	85.75	44.19	10	54.19	0.5419	0.0014	0.0154
10/5/2017	0.0651	135.23	91.61	43.62	10	53.62	0.5362	0.0013	0.0125
10/8/2017	0.0768	125.05	81.69	43.36	10	53.36	0.5336	0.0080	0.0113
10/9/2017	0.0972	125.17	80.22	44.95	10	54.95	0.5495	0.0220	0.0196
10/9/2017	0.1724	125.45	80.83	44.62	10	54.62	0.5462	0.0127	0.0177
10/9/2017	0.0753	125.41	81.11	44.3	10	54.3	0.543	0.0171	0.0160
10/10/2017	0.0534	131.53	88.93	42.6	10	52.6	0.526	0.0052	0.0078
10/11/2017	0.0650	124.98	82.68	42.3	10	52.3	0.523	0.0062	0.0066
10/23/2017	0.0553	121.99	81.28	40.71	10	50.71	0.5071	0.0026	0.0007
10/23/2017	0.1142	122.09	75.14	46.95	10	56.95	0.5695	0.0425	0.0320
10/24/2017	0.1004	120.97	75.68	45.29	10	55.29	0.5529	0.0391	0.0215
10/24/2017	0.0991	120.23	75.39	44.84	10	54.84	0.5484	0.0323	0.0189
10/29/2017	0.1067	119.27	71.96	47.31	10	57.31	0.5731	0.0641	0.0345
10/30/2017	0.1050	122.52	77.45	45.07	10	55.07	0.5507	0.0390	0.0202
11/3/2017	0.0781	130.27	88.09	42.18	10	52.18	0.5218	0.0096	0.0061
11/6/2017	0.1360	139.53	86.95	52.58	10	62.58	0.6258	0.1250	0.0794
11/6/2017	0.1275	140.18	88.13	52.05	10	62.05	0.6205	0.0835	0.0742
11/7/2017	0.1194	139.7	88.06	51.64	10	61.64	0.6164	0.0744	0.0703
11/7/2017	0.1315	140.14	87.26	52.88	10	62.88	0.6288	0.1105	0.0825
1/21/2018	0.0862	133.87	87.84	46.03	10.2	56.23	0.5623	0.0246	0.0273
3/16/2018	0.0705	130.76	85.8	44.96	10.2	55.16	0.5516	0.0038	0.0208
3/23/2018	0.0791	134.69	88.54	46.15	10.2	56.35	0.5635	0.0129	0.0280
3/30/2018	0.1219	136.81	84.83	51.98	10.2	62.18	0.6218	0.0997	0.0755
4/5/2018	0.0716	135.58	87.75	47.83	10.2	58.03	0.5803	0.0422	0.0397
7/6/2018	0.0689	136.1	90.7	45.4	10.2	55.6	0.556	0.0225	0.0234
7/6/2018	0.0570	136	90.75	45.25	10.2	55.45	0.5545	0.0155	0.0225
9/20/2018	0.0777	133.33	88.83	44.5	10.2	54.7	0.547	0.0169	0.0182
9/20/2018	0.0983	132.99	88.48	44.51	10.2	54.71	0.5471	0.0172	0.0182
10/2/2018	0.0796	134.19	89.32	44.87	10.2	55.07	0.5507	0.0128	0.0202
10/16/2018	0.0924	136.49	92.06	44.43	10.2	54.63	0.5463	0.0135	0.0178
10/16/2018	0.0921	136.13	91.7	44.43	10.2	54.63	0.5463	0.0142	0.0178
11/1/2018	0.0975	118.94	76.1	42.84	10.2	53.04	0.5304	0.0091	0.0098
11/13/2018	0.0985	133.67	87.02	46.65	10.2	56.85	0.5685	0.0219	0.0314
1/15/2019	0.0850	134.1	88.19	45.91	10.2	56.11	0.5611	0.0105	0.0265
1/15/2019	0.0860	133.82	87.99	45.83	10.2	56.03	0.5603	0.0092	0.0260
1/29/2019	0.1009	122.53	76.57	45.96	10.2	56.16	0.5616	0.0165	0.0268
7/11/2019	0.4313	193.72	80.33	113.39	10.2	123.59	1.2359	1.7344	1.7559
12/10/2019	0.1268	140.13	81.16	58.97	10.2	69.17	0.6917	0.1249	0.1579
12/17/2019	0.1386	137.68	75.86	61.82	10.2	72.02	0.7202	0.1924	0.1996
2/13/2020	0.1326	1052.3	991.29	61	10.2	71.2	0.712	0.2879	0.1871
2/13/2020	0.1517	1051.4	991.72	59.7	10.2	69.9	0.699	0.2551	0.1682
12/31/2020	0.1040	1067	1005.92	61.048	10.2	71.248	0.71248	0.1360	0.1878
12/31/2020	0.0970	1067.1	1006.15	60.919	10.2	71.119	0.71119	0.1180	0.1859
12/31/2020	0.1020	1067.5	1006.54	61.023	10.2	71.223	0.71223	0.1400	0.1875
2/28/2021	0.3810	1094.9	995.29	99.6	10.2	109.8	1.098	1.2464	1.1907
2/28/2021	0.3940	1090.8	995.20	95.6	10.2	105.8	1.058	1.1415	1.0471
2/28/2021	0.3950	1087.2	995.09	92.1	10.2	102.3	1.023	0.9689	0.9290
2/28/2021	0.3760	1084	994.94	89.1	10.2	99.3	0.993	0.8691	0.8333
2/28/2021	0.3810	1083.4	994.56	88.8	10.2	99	0.99	0.7542	0.8241
2/28/2021	0.4080	1084.6	993.92	90.7	10.2	100.9	1.009	0.7256	0.8837

Table A15-2. Modeled streamflow at Site 15, West Run Watershed, Morgantown, WV, U.S.A.

Cross- Section Area (m ²)	A (Cross Section area of flow)	P (Wetted Perimete r)	RH=A/P Hydraulic Radius (m)	Observed Slope (m)	Calculated Slope using ArcGIS (m)	Roughness Coefficient (n)	Manning Discharge (m ³ /s) (Obs Slope)	Manning Discharge (m ³ /s) (Calc Slope)	Cheyzy Coefficient (C)	Cheyzy Discharge (m ³ /s) (Obs Slope)	Cheyzy Discharge (m ³ /s) (Calc Slope)	Dingman & Sharma Discharge (m ³ /s) (Obs. Slope)	Dingman & Sharma Discharge (m ³ /s) (Calc Slope)
2.6	0.756	2.5883	0.291951	0.01	0.041	0.135	0.246341803	0.498804134	6.033250233	0.246341803	0.498804134	0.417295599	0.540941857
2.6	0.742	2.5837	0.287291	0.01	0.041	0.135	0.239389746	0.484727291	6.017089305	0.239389746	0.484727291	0.406003993	0.526304506
2.6	0.733	2.5802	0.284156	0.01	0.041	0.135	0.234733215	0.475298535	6.006098371	0.234733215	0.475298535	0.398422018	0.516475963
2.6	0.064	0.9916	0.064542	0.01	0.041	0.135	0.007627962	0.015445445	4.691446925	0.007627962	0.015445445	0.012607333	0.016342934
2.6	0.754	2.5879	0.291505	0.01	0.041	0.135	0.245675041	0.497454043	6.031712736	0.245675041	0.497454043	0.4162141	0.539539906
2.6	0.749	2.5861	0.28967	0.01	0.041	0.135	0.242935057	0.491906	6.025367071	0.242935057	0.491906	0.411766539	0.533774516
2.6	0.744	2.5843	0.287898	0.01	0.041	0.135	0.240294011	0.486558289	6.019207923	0.240294011	0.486558289	0.407474616	0.52821088
2.6	0.717	2.5732	0.278602	0.01	0.041	0.135	0.226520987	0.45867004	5.986369688	0.226520987	0.45867004	0.385014114	0.499095246
2.6	0.712	2.5710	0.276981	0.01	0.041	0.135	0.224134603	0.453837981	5.980550147	0.224134603	0.453837981	0.381109284	0.494033401
2.6	0.687	2.5579	0.268477	0.01	0.041	0.135	0.221701669	0.428663208	5.949551258	0.221701669	0.428663208	0.360703232	0.467580959
2.6	0.786	2.5967	0.302808	0.01	0.041	0.135	0.262645653	0.531816915	6.07007477	0.262645653	0.531816915	0.443643156	0.575096295
2.6	0.760	2.5897	0.293405	0.01	0.041	0.135	0.248515623	0.503205784	6.038244979	0.248515623	0.503205784	0.420819404	0.545509779
2.6	0.753	2.5873	0.290893	0.01	0.041	0.135	0.244759854	0.495600931	6.029598151	0.244759854	0.495600931	0.414729145	0.537614954
2.6	0.792	2.5979	0.304877	0.01	0.041	0.135	0.265768438	0.538140073	6.076968242	0.265768438	0.538140073	0.448668136	0.581610196
2.6	0.756	2.5885	0.292175	0.01	0.041	0.135	0.246675555	0.49947993	6.034018864	0.246675555	0.49947993	0.417836833	0.541643461
2.6	0.710	2.5700	0.276334	0.01	0.041	0.135	0.223183695	0.451912539	5.978219953	0.223183695	0.451912539	0.379552241	0.492015
2.6	0.251	2.1038	0.119308	0.01	0.041	0.135	0.045059476	0.091238484	5.197299888	0.045059476	0.091238484	0.08007957	0.103807448
2.6	0.868	2.6036	0.33267	0.01	0.041	0.135	0.308954073	0.617817557	6.308954073	0.308954073	0.617817557	0.517436898	0.670755401
2.6	0.861	2.6039	0.330719	0.01	0.041	0.135	0.305059683	0.617698779	6.159933655	0.305059683	0.617698779	0.511291271	0.662788801
2.6	0.881	2.6026	0.338483	0.01	0.041	0.135	0.316935161	0.64174479	6.183805415	0.316935161	0.64174479	0.529996791	0.687036837
2.6	0.775	2.5940	0.298702	0.01	0.041	0.135	0.256463097	0.519298192	6.056279659	0.256463097	0.519298192	0.433674091	0.562173359
2.6	0.758	2.5890	0.292677	0.01	0.041	0.135	0.247427403	0.501002306	6.035748002	0.247427403	0.501002306	0.419055792	0.543223602
2.6	0.777	2.5944	0.299383	0.01	0.041	0.135	0.257487738	0.521372933	6.058579774	0.257487738	0.521372933	0.435328153	0.564317525
2.6	0.870	2.6035	0.334078	0.01	0.041	0.135	0.310195471	0.628097957	6.170319116	0.310195471	0.628097957	0.519393571	0.673291843
2.6	0.804	2.6000	0.309049	0.01	0.041	0.135	0.27207806	0.550916083	6.09075049	0.27207806	0.550916083	0.458799853	0.594743978
2.6	0.121	1.891	0.063987	0.01	0.041	0.135	0.014338845	0.029033948	4.684700939	0.014338845	0.029033948	0.026520489	0.03437861
2.6	0.119	1.8666	0.063752	0.01	0.041	0.135	0.014067286	0.028484084	4.681828649	0.014067286	0.028484084	0.025968784	0.033663433
2.6	0.101	1.4506	0.069626	0.01	0.041	0.135	0.012662032	0.025638661	4.751111051	0.012662032	0.025638661	0.022192958	0.028768816
2.6	0.125	1.5536	0.080458	0.01	0.041	0.135	0.017256661	0.034942076	4.867000209	0.017256661	0.034942076	0.030195381	0.039142386
2.6	0.097	1.378	0.070392	0.01	0.041	0.135	0.012249536	0.02480342	4.759777492	0.012249536	0.02480342	0.021258323	0.027557244
2.6	0.12	1.4796	0.081103	0.01	0.041	0.135	0.016654775	0.033723348	4.873478473	0.016654775	0.033723348	0.028875607	0.037431558
2.6	0.119	1.4792	0.080449	0.01	0.041	0.135	0.016427062	0.033262266	4.866905444	0.016427062	0.033262266	0.028501083	0.036946061
2.6	0.119	1.4138	0.08417	0.01	0.041	0.135	0.016929827	0.034280287	4.903724494	0.016929827	0.034280287	0.029021304	0.037620426
2.6	0.143	1.645	0.08693	0.01	0.041	0.135	0.020786547	0.04208955	4.930162727	0.020786547	0.04208955	0.03646817	0.047273827
2.6	0.11	1.4654	0.075065	0.01	0.041	0.135	0.014499396	0.02935904	4.811040149	0.014499396	0.02935904	0.025279296	0.032769646
2.6	0.111	1.4672	0.075654	0.01	0.041	0.135	0.014707707	0.029780838	4.817316437	0.014707707	0.029780838	0.025629142	0.033223153
2.6	0.131	1.4968	0.08752	0.01	0.041	0.135	0.019128278	0.038731811	4.935723453	0.019128278	0.038731811	0.032994305	0.042770642
2.6	2.169	5.8916	0.368151	0.01	0.041	0.135	0.825296461	1.671097967	6.271006938	0.825296461	1.671097967	1.577174413	2.044497134
2.6	0.242	2.1586	0.11211	0.01	0.041	0.135	0.041678338	0.084392202	5.143673937	0.041678338	0.084392202	0.074835808	0.09700994
2.6	0.338	2.7152	0.124484	0.01	0.041	0.135	0.062420347	0.126391571	5.234220862	0.062420347	0.126391571	0.115478727	0.149695509
2.6	0.521	4.1892	0.124367	0.01	0.041	0.135	0.096155701	0.194700456	5.233400878	0.096155701	0.194700456	0.191765311	0.248586096
2.6	0.433	3.1614	0.136965	0.01	0.041	0.135	0.085223577	0.172564592	5.318236415	0.085223577	0.172564592	0.160428096	0.207963546
2.6	0.183	1.9618	0.093282	0.01	0.041	0.135	0.02788142	0.056455573	4.988450014	0.02788142	0.056455573	0.05009685	0.064940736
2.6	0.167	1.9094	0.087462	0.01	0.041	0.135	0.024374127	0.049353846	4.935178027	0.024374127	0.049353846	0.04385418	0.056848338
2.6	0.174	1.9182	0.09071	0.01	0.041	0.135	0.026020705	0.052687911	4.96526149	0.026020705	0.052687911	0.046694224	0.060529898
2.6	1.943	5.866	0.331231	0.01	0.041	0.135	0.68901106	1.395141064	6.16152226	0.68901106	1.395141064	1.328824542	1.722560262
2.6	2.043	5.9704	0.342188	0.01	0.041	0.135	0.740362745	1.4991203	6.195034384	0.740362745	1.4991203	1.427866216	1.850948356
2.6	1.984	5.818	0.341011	0.01	0.041	0.135	0.717331441	1.452485464	6.191476421	0.717331441	1.452485464	1.377717914	1.785940924
2.6	1.863	5.7054	0.326533	0.01	0.041	0.135	0.654380362	1.325019245	6.146869944	0.654380362	1.325019245	1.257671242	1.63032397
2.6	1.887	5.715	0.330184	0.01	0.041	0.135	0.667741818	1.352074131	6.158271651	0.667741818	1.352074131	1.282388025	1.662364429
2.6	2.053	5.8452	0.351228	0.01	0.041	0.135	0.757033149	1.532875296	6.222016529	0.757033149	1.532875296	1.451124972	1.881098769

Figure A15-1. Observed and modeled rating curves and streamflow from Site 15, West Run Watershed, Morgantown, West Virginia, U.S.A.

Table A15-3. Polynomial rating equations and R^2 values for observed and modeled rating curves at Site 15, West Run Watershed, Morgantown, WV, U.S.A.

	R² Value	Polynomial Equation
Observed Curve	0.99	$y = 2.8601x^2 - 2.5768x + 0.5719$
Manning's Curve (Obs Slope)	0.68	$y = 1.8729x^2 - 2.0178x + 0.6895$
Manning's Curve (Calc Slope)	0.68	$y = 3.7924x^2 - 4.0858x + 1.3961$
Chezy's Curve (Obs Slope)	0.68	$y = 1.8729x^2 - 2.0178x + 0.6895$
Chezy's Curve (Calc Slope)	0.68	$y = 3.7924x^2 - 4.0858x + 1.3961$
Dingman and Sharma's Curve (Obs Slope)	0.73	$y = 3.461x^2 - 3.5824x + 1.1681$
Dingman and Sharma's Curve (Calc Slope)	0.73	$y = 4.4865x^2 - 4.6438x + 1.5142$

Table A15-4. Descriptive statistics for observed and modeled streamflow used to generate the rating curves for Site 15, West Run Watershed, Morgantown, WV, U.S.A.

	Sample Size	Mean (m³/s)	St. Dev.	SE of Mean
Observed	51	0.191	0.377	0.053
Manning's Curve (Obs Slope)	51	0.226	0.228	0.032
Manning's Curve (Calc Slope)	51	0.458	0.462	0.065
Chezy's Curve (Obs Slope)	51	0.226	0.228	0.032
Chezy's Curve (Calc Slope)	51	0.458	0.462	0.065
Dingman and Sharma's Curve (Obs Slope)	51	0.407	0.437	0.061
Dingman and Sharma's Curve (Calc Slope)	51	0.527	0.566	0.079

Table A15-5. P-values of the statistical analyses (post-hoc ANOVA) for observed and modeled rating curves at Site 15, West Run Watershed, Morgantown, WV, U.S.A.

	Observed Curve	Rating Equation Curve	Manning's Curve (Obs Slope)	Manning's Curve (Calc Slope)	Chezy's Curve (Obs Slope)	Chezy's Curve (Calc Slope)	Dingman and Sharma's Curve (Obs Slope)	Dingman and Sharma's Curve (Calc Slope)
Observed Curve	-	1	1	0.02*	1	0.02*	0.13	<0.05*
Rating Equation Curve	-	-	1	0.02*	1	0.02*	0.13	<0.05*
Manning's Curve (Obs Slope)	-	-	-	0.08	1	0.08	0.33	0.05
Manning's Curve (Calc Slope)	-	-	-	-	0.80	1	1	0.99
Chezy's Curve (Obs Slope)	-	-	-	-	-	0.08	0.33	0.05*
Chezy's Curve (Calc Slope)	-	-	-	-	-	-	1	0.99
Dingman and Sharma's Curve (Obs Slope)	-	-	-	-	-	-	-	0.81
Dingman and Sharma's Curve (Calc Slope)	-	-	-	-	-	-	-	-

*= indicates that the difference of the means is significant at the 0.05 level.

Figure A15-2. Box and whisker plots for the results of the statistical analyses (post-hoc ANOVA) of observed and modeled rating curves at Site 15, West Run Watershed, Morgantown, WV, U.S.A.

Figure A15-3. Cross-sectional profile of WRW Site 15, plotting the stream channel's shape, water surface, and bankfull. The profile is created with a Channel Width of 0= Left Bank facing downstream.

Figure A15-4. Plan view profile of WRW Site 15, West Run Watershed, Morgantown, WV, U.S.A. (Figure 2). Showing the positioning of stilling well in relation to where the streamflow was measured. Along with the channel width at the stilling well, point where cross-sections were performed, and 15.5m upstream and downstream from the stilling well.

Figure A15-5. Photographs showing channel characteristics at Site #15, West Run Watershed, Morgantown, WV, U.S.A. Photo 1 was taken looking upstream in the channel. Photo 2 was taken from the left bank looking downstream.

APPENDIX 16: Site 16

Table A16-1. Streamflow measurements and stage collected at Site 16, West Run Watershed, Morgantown, WV, U.S.A. (Figure 2).

Date	Mean Depth of Cross-Section (m)	Stage(PT in cm)	Barometric Pressure (in cm)	Pressure Corrected Stage (cm)	Stilling Well Offset (cm)	P-Corrected Stage + Offset (cm)	P-Corrected Stage + Offset (m)	SonTec Discharge (m3/s)	Rating Equation Discharge (m3/s)
3/16/2018	0.0305	94.54	86.4	8.14	4.1	12.2675	0.122675	0.0026	0.0010
3/23/2018	0.0457	97.78	88.65	9.13	4.1	13.2575	0.132575	0.0050	0.0013
4/5/2018	0.0445	102.36	88.31	14.05	4.1	18.1775	0.181775	0.0129	0.0071
10/2/2018	0.0744	100.99	89.07	11.92	4.1	16.0475	0.160475	0.0017	0.0037
10/2/2018	0.0738	100.76	88.81	11.95	4.1	16.0775	0.160775	0.0015	0.0037
10/2/2018	0.0725	100.61	88.8	11.81	4.1	15.9375	0.159375	0.0023	0.0035
10/16/2018	0.0958	105.06	92.28	12.78	4.1	16.9075	0.169075	0.0040	0.0049
10/16/2018	0.0942	105.03	92.33	12.7	4.1	16.8275	0.168275	0.0029	0.0047
10/25/2018	0.0710	102.63	90.72	11.91	4.1	16.0375	0.160375	0.0006	0.0036
11/1/2018	0.0985	87.83	76.15	11.68	4.1	15.8075	0.158075	0.0033	0.0034
11/13/2018	0.0954	100.76	86.96	13.8	4.1	17.9275	0.179275	0.0036	0.0066
1/29/2019	0.0722	90.56	76.77	13.79	4.1	17.9175	0.179175	0.0045	0.0066
12/10/2019	0.1361	98.71	80.83	17.88	4.1	22.0075	0.220075	0.0214	0.0167
2/13/2020	0.0983	1021.4	990.81	30.6	4.1	34.7	0.347	0.0769	0.0804
6/13/2021	0.1088	1023.9	996.62	27.3	4.1	31.4	0.314	0.0680	0.0592
6/13/2021	0.1207	1027.5	998.26	29.2	4.1	33.3	0.333	0.0719	0.0710
6/13/2021	0.1140	1031.6	996.84	34.8	4.1	38.9	0.389	0.1110	0.1123
6/13/2021	0.1289	1036	996.67	39.3	4.1	43.4	0.434	0.1548	0.1524
6/13/2021	0.1155	1034	996.21	37.8	4.1	41.9	0.419	0.1399	0.1384
6/13/2021	0.0927	1029.3	995.58	33.7	4.1	37.8	0.378	0.0931	0.1035
8/10/2021	0.1120	1043.6	1005.44	38.2	4.1	42.3	0.423	0.1445	0.1421
8/10/2021	0.1020	1039.6	1005.00	34.6	4.1	38.7	0.387	0.1103	0.1107

Table A16-2. Modeled streamflow at Site 16, West Run Watershed, Morgantown, WV, U.S.A.

Cross-Section Area (m ²)	A (Cross Section area of flow)	P (Wetted Perimeter)	RH=A/P Hydraulic Radius (m)	Observed Slope (m)	Calculated Slope using ArcGIS (m)	Roughness Coefficient (n)	Manning Discharge (m ³ /s) (Obs Slope)	Manning Discharge (m ³ /s) (Calc Slope)	Chezy Coefficient (C)	Chezy Discharge (m ³ /s) (Obs Slope)	Chezy Discharge (m ³ /s) (Calc Slope)	Dingman & Sharma Discharge (m ³ /s) (Obs. Slope)	Dingman & Sharma Discharge (m ³ /s) (Calc Slope)
1.57	0.073	1.5796	0.046382	0.04	0.084	0.135	0.014011763	0.020304974	4.440088034	0.014011763	0.020304974	0.01671801	0.01846992
1.57	0.089	1.6207	0.054953	0.04	0.084	0.135	0.019071568	0.027637328	4.567349244	0.019071568	0.027637328	0.022496394	0.024853831
1.57	0.168	1.8127	0.092446	0.04	0.084	0.135	0.050757772	0.073554999	4.980976624	0.050757772	0.073554999	0.058140625	0.064233283
1.57	0.072	1.137	0.063325	0.04	0.084	0.135	0.016946372	0.024557627	4.676578587	0.016946372	0.024557627	0.018552462	0.020496607
1.57	0.073	1.1382	0.064136	0.04	0.084	0.135	0.017328273	0.025111053	4.686517877	0.017328273	0.025111053	0.018951393	0.020937343
1.57	0.072	1.1364	0.063358	0.04	0.084	0.135	0.016952337	0.02456627	4.676990022	0.016952337	0.02456627	0.01855638	0.020500935
1.57	0.098	1.1886	0.08245	0.04	0.084	0.135	0.027503156	0.03985586	4.886875668	0.027503156	0.03985586	0.029600977	0.032702915
1.57	0.093	1.1792	0.078867	0.04	0.084	0.135	0.025338223	0.036718574	4.850823556	0.025338223	0.036718574	0.027347045	0.03021279
1.57	0.07	1.1328	0.061794	0.04	0.084	0.135	0.016209046	0.02348914	4.657544698	0.016209046	0.02348914	0.017774592	0.019637223
1.57	0.113	3.115	0.036276	0.04	0.084	0.135	0.018345164	0.026584668	4.261897137	0.018345164	0.026584668	0.025190158	0.027829879
1.57	0.109	3.049	0.035749	0.04	0.084	0.135	0.017524089	0.025394817	4.251521801	0.017524089	0.025394817	0.024006599	0.026522292
1.57	0.082	1.2872	0.063704	0.04	0.084	0.135	0.019377093	0.028080076	4.68123958	0.019377093	0.028080076	0.021661698	0.023931665
1.57	0.121	1.3392	0.090352	0.04	0.084	0.135	0.036094543	0.052305962	4.961993829	0.036094543	0.052305962	0.039319223	0.043439554
1.57	0.157	1.7966	0.087387	0.04	0.084	0.135	0.045803084	0.066374974	4.934474864	0.045803084	0.066374974	0.052661268	0.058179735
1.57	0.148	2.275	0.065055	0.04	0.084	0.135	0.035465941	0.051395031	4.69763876	0.035465941	0.051395031	0.043666747	0.048242662
1.57	0.151	2.376	0.063552	0.04	0.084	0.135	0.035625435	0.051626161	4.679376432	0.035625435	0.051626161	0.044290837	0.048932151
1.57	0.243	2.362	0.102879	0.04	0.084	0.135	0.079041181	0.114541553	5.070537063	0.079041181	0.114541553	0.093835772	0.103668987
1.57	0.27493	2.392	0.114937	0.04	0.084	0.135	0.09628508	0.139530337	5.165072132	0.09628508	0.139530337	0.113374051	0.125254716
1.57	0.23795	2.289	0.103954	0.04	0.084	0.135	0.077936676	0.112940974	5.079327521	0.077936676	0.112940974	0.091933845	0.101567753
1.57	0.18348	2.167	0.08467	0.04	0.084	0.135	0.052412898	0.075953505	4.90856487	0.052412898	0.075953505	0.062431422	0.068973721
1.57	0.18	1.824	0.098684	0.04	0.084	0.135	0.056946519	0.082523346	5.035479629	0.056946519	0.082523346	0.064901605	0.071702758
1.57	0.16287	1.804	0.090283	0.04	0.084	0.135	0.048559443	0.070369319	4.961355253	0.048559443	0.070369319	0.055699738	0.061536611

Figure A16-1. Observed and modeled rating curves and streamflow from Site 16, West Run Watershed, Morgantown, West Virginia, U.S.A.

Table A16-3. Polynomial rating equations and R^2 values for observed and modeled rating curves at Site 16, West Run Watershed, Morgantown, WV, U.S.A.

	R² Value	Polynomial Equation
Observed Curve	1	$y = 1.5195x^2 - 0.3594x + 0.0222$
Manning's Curve (Obs Slope)	0.79	$y = 0.6688x^2 - 0.1891x + 0.0343$
Manning's Curve (Calc Slope)	0.79	$y = 0.9692x^2 - 0.274x + 0.0497$
Chezy's Curve (Obs Slope)	0.79	$y = 0.6688x^2 - 0.1891x + 0.0343$
Chezy's Curve (Calc Slope)	0.79	$y = 0.9692x^2 - 0.274x + 0.0497$
Dingman and Sharma's Curve (Obs Slope)	0.80	$y = 0.7683x^2 - 0.2102x + 0.0383$
Dingman and Sharma's Curve (Calc Slope)	0.80	$y = 0.8488x^2 - 0.2322x + 0.0423$

Table A16-4. Descriptive statistics for observed and modeled streamflow used to generate the rating curves for Site 16, West Run Watershed, Morgantown, WV, U.S.A.

	Sample Size	Mean (m³/s)	St. Dev.	SE of Mean
Observed	22	0.047	0.056	0.012
Manning's Curve (Obs Slope)	22	0.037	0.024	0.005
Manning's Curve (Calc Slope)	22	0.054	0.034	0.007
Chezy's Curve (Obs Slope)	22	0.037	0.024	0.005
Chezy's Curve (Calc Slope)	22	0.054	0.034	0.007
Dingman and Sharma's Curve (Obs Slope)	22	0.044	0.028	0.006
Dingman and Sharma's Curve (Calc Slope)	22	0.048	0.031	0.007

Table A16-5. P-values of the statistical analyses (post-hoc ANOVA) for observed and modeled rating curves at Site 16, West Run Watershed, Morgantown, WV, U.S.A.

	Observed Curve	Rating Equation Curve	Manning's Curve (Obs Slope)	Manning's Curve (Calc Slope)	Chezy's Curve (Obs Slope)	Chezy's Curve (Calc Slope)	Dingman and Sharma's Curve (Obs Slope)	Dingman and Sharma's Curve (Calc Slope)
Observed Curve	-	1	0.99	1	0.99	1	1	1
Rating Equation Curve	-	-	0.99	1	0.99	1	1	1
Manning's Curve (Obs Slope)	-	-	-	0.82	1	0.82	1	0.98
Manning's Curve (Calc Slope)	-	-	-	-	0.82	1	0.98	1
Chezy's Curve (Obs Slope)	-	-	-	-	-	0.82	1	0.98
Chezy's Curve (Calc Slope)	-	-	-	-	-	-	0.98	1
Dingman and Sharma's Curve (Obs Slope)	-	-	-	-	-	-	-	1
Dingman and Sharma's Curve (Calc Slope)	-	-	-	-	-	-	-	-

Figure A16-2. Box and whisker plots for the results of the statistical analyses (post-hoc ANOVA) of observed and modeled rating curves at Site 16, West Run Watershed, Morgantown, WV, U.S.A.

Figure A16-3. Cross-sectional profile of WRW Site 16, plotting the stream channel's shape, water surface, and bankfull. The profile is created with a Channel Width of 0= Left Bank facing downstream.

Figure A16-5. Photographs showing channel characteristics at Site #16, West Run Watershed, Morgantown, WV, U.S.A. Photo 1 was taken looking upstream in the channel. Photo 2 was taken from the left bank looking upstream.

APPENDIX 17: Site 17

Table A17-1. Streamflow measurements and stage collected at Site 17, West Run Watershed, Morgantown, WV, U.S.A. (Figure 2).

Date	Mean Depth of Cross-Section (m)	Stage(PT in cm)	Barometric Pressure (in cm)	Pressure Corrected Stage (cm)	Stilling Well Offset (cm)	P-Corrected Stage + Offset (cm)	P-Corrected Stage + Offset (m)	SonTec Discharge (m3/s)	Rating Equation Discharge (m3/s)
10/24/2017	0.0831	136.09	75.55	60.54	0	60.54	0.6054	0.0016	0.0067
10/24/2017	0.0550	135.64	75.57	60.07	0	60.07	0.6007	0.0011	0.0055
11/6/2017	0.2248	154.15	88.06	66.09	0	66.09	0.6609	0.0134	0.0324
11/7/2017	0.2202	150.13	87.11	63.02	0	63.02	0.6302	0.0142	0.0157
1/15/2019	0.0884	141.36	88.56	52.8	2	54.8	0.548	0.0041	0.0015
1/29/2019	0.0686	134.53	76.6	57.93	2	59.93	0.5993	0.0118	0.0051
6/18/2019	0.0741	141.53	82.79	58.74	2	60.74	0.6074	0.0133	0.0073
6/18/2019	0.0744	141.33	82.67	58.66	2	60.66	0.6066	0.0152	0.0070
12/10/2019	0.1131	148.35	81.2	67.15	2	69.15	0.6915	0.0334	0.0554
1/4/2020	0.1257	141.17	73.63	67.54	2	69.54	0.6954	0.0517	0.0587
1/4/2020	0.1372	140.78	74.01	66.77	2	68.77	0.6877	0.0565	0.0522
2/24/2021	0.1580	1058.9	996.73	62.2	2	64.2	0.642	0.0313	0.0214
2/24/2021	0.1540	1058.6	996.16	62.4	2	64.4	0.644	0.0299	0.0224
2/24/2021	0.1660	1058.8	995.83	63	2	65	0.65	0.0319	0.0258
2/24/2021	0.1620	1058.5	995.78	62.7	2	64.7	0.647	0.0323	0.0241
2/24/2021	0.1650	1058.1	995.44	62.7	2	64.7	0.647	0.0331	0.0241
2/24/2021	0.1550	1058	995.24	62.8	2	64.8	0.648	0.0334	0.0246
2/24/2021	0.1690	1057.5	995.04	62.5	2	64.5	0.645	0.0323	0.0230
2/24/2021	0.1660	1057.1	994.69	62.4	2	64.4	0.644	0.0364	0.0224
2/28/2021	0.2410	1076.1	993.76	82.3	2	84.3	0.843	0.3023	0.2603
2/28/2021	0.2210	1076.4	993.75	82.6	2	84.6	0.846	0.3112	0.2659
2/28/2021	0.2080	1078.1	993.67	84.4	2	86.4	0.864	0.3193	0.3007
2/28/2021	0.2130	1079.7	993.49	86.2	2	88.2	0.882	0.304	0.3376
2/28/2021	0.2060	1078	992.84	85.2	2	87.2	0.872	0.2837	0.3168
2/28/2021	0.2190	1075.3	992.90	82.4	2	84.4	0.844	0.3039	0.2621
2/28/2021	0.2250	1077.5	992.63	84.9	2	86.9	0.869	0.3108	0.3107
2/28/2021	0.2110	1077.9	992.26	85.6	2	87.6	0.876	0.2792	0.3251
9/1/2021	0.3130	1077.9	989.21	88.7	2	90.7	0.907	0.3541	0.3925
9/1/2021	0.3140	1078.1	989.46	88.6	2	90.6	0.906	0.4142	0.3903
9/1/2021	0.3130	1077	989.57	87.4	2	89.4	0.894	0.4145	0.3635
9/1/2021	0.3060	1076.4	989.69	86.7	2	88.7	0.887	0.3567	0.3483
9/1/2021	0.2980	1077.5	989.83	87.7	2	89.7	0.897	0.3735	0.3701
9/1/2021	0.2980	1077.2	989.97	87.2	2	89.2	0.892	0.3872	0.3591
9/1/2021	0.2920	1076.6	989.94	86.7	2	88.7	0.887	0.3578	0.3483
9/1/2021	0.2860	1076.5	990.04	86.5	2	88.5	0.885	0.3719	0.3440
9/1/2021	0.2880	1075.9	990.03	85.9	2	87.9	0.879	0.3177	0.3313
9/1/2021	0.2850	1075.7	990.09	85.6	2	87.6	0.876	0.3119	0.3251
9/1/2021	0.2740	1074.5	990.28	84.2	2	86.2	0.862	0.3013	0.2967
9/1/2021	0.2530	1073.9	990.22	83.7	2	85.7	0.857	0.2713	0.2869
9/1/2021	0.2520	1074.8	990.24	84.6	2	86.6	0.866	0.2695	0.3047
9/1/2021	0.2730	1074.3	990.27	84	2	86	0.86	0.268	0.2928
9/1/2021	0.2640	1074.2	990.37	83.8	2	85.8	0.858	0.2477	0.2888

Table A17-2. Modeled streamflow at Site 17, West Run Watershed, Morgantown, WV, U.S.A.

Cross-Section Area (m ²)	A (Cross Section area of flow)	P (Wetted Perimeter)	RH=A/P Hydraulic Radius (m)	Observed Slope (m)	Calculated Slope using ArcGIS (m)	Roughness Coefficient (n)	Manning Discharge (m ³ /s) (Obs Slope)	Manning Discharge (m ³ /s) (Calc Slope)	Chezy Coefficient (C)	Chezy Discharge (m ³ /s) (Obs Slope)	Chezy Discharge (m ³ /s) (Calc Slope)	Dingman & Sharma Discharge (m ³ /s) (Obs. Slope)	Dingman & Sharma Discharge (m ³ /s) (Calc Slope)
0.85	0.051	0.7762	0.065705	0.02	0.06	0.16	0.007340003	0.012713258	3.970203552	0.007340003	0.012713258	0.011181969	0.013310364
0.85	0.045	0.7578	0.059382	0.02	0.06	0.16	0.006054052	0.010485925	3.903818964	0.006054052	0.010485925	0.009272168	0.011037048
0.85	0.214	1.3814	0.154915	0.02	0.06	0.16	0.054559662	0.094500106	4.580319124	0.054559662	0.094500106	0.084744776	0.100875241
0.85	0.207	1.3518	0.153129	0.02	0.06	0.16	0.05236856	0.090705006	4.571474847	0.05236856	0.090705006	0.081125283	0.096566808
0.85	0.067	0.9388	0.071368	0.02	0.06	0.16	0.010189142	0.017648112	4.025288115	0.010189142	0.017648112	0.015917919	0.018947762
0.85	0.047	0.8232	0.057094	0.02	0.06	0.16	0.006159629	0.01066879	3.878336017	0.006159629	0.01066879	0.009605227	0.011433502
0.85	0.056	0.9098	0.061552	0.02	0.06	0.16	0.007716336	0.013365085	3.927236298	0.007716336	0.013365085	0.012156855	0.014470812
0.85	0.057	0.9106	0.062596	0.02	0.06	0.16	0.007942697	0.013757155	3.938261522	0.007942697	0.013757155	0.012495681	0.014874131
0.85	0.112	1.2172	0.092014	0.02	0.06	0.16	0.020176713	0.034947093	4.199420499	0.020176713	0.034947093	0.032194006	0.038321868
0.85	0.125	1.2424	0.100612	0.02	0.06	0.16	0.02390034	0.042405652	4.262405652	0.02390034	0.042405652	0.037952005	0.045173584
0.85	0.136	1.2654	0.107476	0.02	0.06	0.16	0.027173233	0.04706542	4.309549404	0.027173233	0.04706542	0.043019506	0.051207912
0.85	0.192	1.5342	0.125147	0.02	0.06	0.16	0.042459585	0.073542158	4.42028114	0.042459585	0.073542158	0.068514089	0.081555178
0.85	0.188	1.5266	0.123149	0.02	0.06	0.16	0.041131504	0.071241855	4.408445227	0.041131504	0.071241855	0.066414062	0.079055428
0.85	0.203	1.5516	0.130833	0.02	0.06	0.16	0.046241853	0.080093239	4.453137056	0.046241853	0.080093239	0.074452487	0.0886239
0.85	0.197	1.5428	0.12769	0.02	0.06	0.16	0.044153551	0.076476194	4.435127575	0.044153551	0.076476194	0.071182194	0.084731134
0.85	0.201	1.5496	0.129711	0.02	0.06	0.16	0.04552417	0.078850176	4.446750463	0.04552417	0.078850176	0.073339746	0.087299359
0.85	0.188	1.528	0.123037	0.02	0.06	0.16	0.041106376	0.071198332	4.407771778	0.041106376	0.071198332	0.066389715	0.079025646
0.85	0.219	1.6326	0.134142	0.02	0.06	0.16	0.050724216	0.08785692	4.471714533	0.050724216	0.08785692	0.082198998	0.097844896
0.85	0.215	1.6266	0.132178	0.02	0.06	0.16	0.049310409	0.085408133	4.460733722	0.049310409	0.085408133	0.079967448	0.095188589
0.85	0.404	2.098	0.192564	0.02	0.06	0.16	0.119076749	0.206246979	4.749442829	0.119076749	0.206246979	0.194811927	0.231892761
0.85	0.388	2.1956	0.176717	0.02	0.06	0.16	0.107997179	0.1870566	4.681946369	0.107997179	0.1870566	0.179519184	0.213689171
0.85	0.381	2.2456	0.169665	0.02	0.06	0.16	0.103208399	0.178762191	4.65027654	0.103208399	0.178762191	0.172886816	0.205794387
0.85	0.39	2.2558	0.172888	0.02	0.06	0.16	0.106979927	0.18529467	4.664882257	0.106979927	0.18529467	0.179029352	0.213106104
0.85	0.376	2.2404	0.167827	0.02	0.06	0.16	0.101117048	0.175139864	4.641842467	0.101117048	0.175139864	0.169488448	0.201749168
0.85	0.384	2.1916	0.175214	0.02	0.06	0.16	0.106277059	0.184077266	4.675287684	0.106277059	0.184077266	0.176745493	0.210387531
0.85	0.378	2.127	0.177715	0.02	0.06	0.16	0.105609509	0.182921035	4.686342967	0.105609509	0.182921035	0.174496795	0.207710812
0.85	0.354	2.0986	0.168684	0.02	0.06	0.16	0.095524331	0.165452995	4.645783312	0.095524331	0.165452995	0.158237755	0.188356999
0.85	0.54929	2.379	0.230891	0.02	0.06	0.16	0.182726502	0.316491586	4.895321572	0.182726502	0.316491586	0.30036556	0.357537652
0.85	0.55103	2.381	0.231428	0.02	0.06	0.16	0.183589353	0.317986087	4.897216741	0.183589353	0.317986087	0.301762139	0.359200059
0.85	0.54813	2.379	0.230404	0.02	0.06	0.16	0.182083814	0.315378417	4.89359705	0.182083814	0.315378417	0.299368383	0.356350671
0.85	0.53593	2.365	0.226609	0.02	0.06	0.16	0.176070947	0.304963825	4.880071344	0.176070947	0.304963825	0.289637228	0.344767272
0.85	0.522	2.349	0.222222	0.02	0.06	0.16	0.169274098	0.293191339	4.864198226	0.169274098	0.293191339	0.278639283	0.331675959
0.85	0.52229	2.349	0.222346	0.02	0.06	0.16	0.169430863	0.293462862	4.864648511	0.169430863	0.293462862	0.278882821	0.331965853
0.85	0.50022	2.299	0.217582	0.02	0.06	0.16	0.159945044	0.277032942	4.847119172	0.159945044	0.277032942	0.262823742	0.312850062
0.85	0.49035	2.287	0.214408	0.02	0.06	0.16	0.15526058	0.268919213	4.835262094	0.15526058	0.268919213	0.255246387	0.30383042
0.85	0.48339	2.252	0.214649	0.02	0.06	0.16	0.153171816	0.265301367	4.836170051	0.153171816	0.265301367	0.251115035	0.298912699
0.85	0.47729	2.246	0.212507	0.02	0.06	0.16	0.150230832	0.260207434	4.828091009	0.150230832	0.260207434	0.246411267	0.293313607
0.85	0.45987	2.224	0.206776	0.02	0.06	0.16	0.142133666	0.246182731	4.806143497	0.142133666	0.246182731	0.233330179	0.277742643
0.85	0.40413	2.106	0.191895	0.02	0.06	0.16	0.118838708	0.20583468	4.746685649	0.118838708	0.20583468	0.194614044	0.231657213
0.85	0.39368	2.066	0.190552	0.02	0.06	0.16	0.11522509	0.199575711	4.74113356	0.11522509	0.199575711	0.188195058	0.224016426
0.85	0.42677	2.108	0.202453	0.02	0.06	0.16	0.130058203	0.225267415	4.789246936	0.130058203	0.225267415	0.211956424	0.252300571
0.85	0.41284	2.092	0.197342	0.02	0.06	0.16	0.123686845	0.214231899	4.768883344	0.123686845	0.214231899	0.201790121	0.240199196

Figure A17-1. Observed and modeled rating curves and streamflow from Site 17, West Run Watershed, Morgantown, West Virginia, U.S.A.

Table A17-3. Polynomial rating equations and R^2 values for observed and modeled rating curves at Site 17, West Run Watershed, Morgantown, WV, U.S.A.

	R² Value	Polynomial Equation
Observed Curve	0.98	$y = 3.3489x^2 - 3.7972x + 1.0815$
Manning's Curve (Obs Slope)	0.89	$y = 1.2628x^2 - 1.4439x + 0.4352$
Manning's Curve (Calc Slope)	0.89	$y = 2.1873x^2 - 2.501x + 0.7537$
Chezy's Curve (Obs Slope)	0.89	$y = 1.2628x^2 - 1.4439x + 0.4352$
Chezy's Curve (Calc Slope)	0.89	$y = 2.1873x^2 - 2.501x + 0.7537$
Dingman and Sharma's Curve (Obs Slope)	0.90	$y = 2.1191x^2 - 2.4314x + 0.7331$
Dingman and Sharma's Curve (Calc Slope)	0.90	$y = 2.5225x^2 - 2.8942x + 0.8726$

Table A17-4. Descriptive statistics for observed and modeled streamflow used to generate the rating curves for Site 17, West Run Watershed, Morgantown, WV, U.S.A.

	Sample Size	Mean (m³/s)	St. Dev.	SE of Mean
Observed	42	0.188	0.154	0.024
Manning's Curve (Obs Slope)	42	0.089	0.059	0.009
Manning's Curve (Calc Slope)	42	0.154	0.103	0.016
Chezy's Curve (Obs Slope)	42	0.089	0.059	0.009
Chezy's Curve (Calc Slope)	42	0.154	0.103	0.016
Dingman and Sharma's Curve (Obs Slope)	42	0.146	0.098	0.015
Dingman and Sharma's Curve (Calc Slope)	42	0.174	0.117	0.018

Table A17-5. P-values of the statistical analyses (post-hoc ANOVA) for observed and modeled rating curves at Site 17, West Run Watershed, Morgantown, WV, U.S.A.

	Observed Curve	Rating Equation Curve	Manning's Curve (Obs Slope)	Manning's Curve (Calc Slope)	Chezy's Curve (Obs Slope)	Chezy's Curve (Calc Slope)	Dingman and Sharma's Curve (Obs Slope)	Dingman and Sharma's Curve (Calc Slope)
Observed Curve	-	1	<0.05*	0.86	<0.05*	0.86	0.66	1
Rating Equation Curve	-	-	<0.05*	0.86	<0.05*	0.86	0.69	1
Manning's Curve (Obs Slope)	-	-	-	0.13	1	0.13	0.27	<0.05*
Manning's Curve (Calc Slope)	-	-	-	-	0.13	1	1	0.99
Chezy's Curve (Obs Slope)	-	-	-	-	-	0.13	0.27	<0.05*
Chezy's Curve (Calc Slope)	-	-	-	-	-	-	1	0.99
Dingman and Sharma's Curve (Obs Slope)	-	-	-	-	-	-	-	0.95
Dingman and Sharma's Curve (Calc Slope)	-	-	-	-	-	-	-	-

*= indicates that the difference of the means is significant at the 0.05 level.

Figure A17-2. Box and whisker plots for the results of the statistical analyses (post-hoc ANOVA) of observed and modeled rating curves at Site 17, West Run Watershed, Morgantown, WV, U.S.A.

Figure A17-3. Cross-sectional profile of WRW Site 17, plotting the stream channel's shape, water surface, and bankfull. The profile is created with a Channel Width of 0= Left Bank facing downstream.

Figure A17-4. Plan view profile of WRW Site 17, West Run Watershed, Morgantown, WV, U.S.A. (Figure 2). Showing the positioning of stilling well in relation to where the streamflow was measured. Along with the channel width at the stilling well, point where cross-sections were performed, and 6.0m upstream and downstream from the stilling well.

Figure A17-5. Photographs showing channel characteristics at Site #17, West Run Watershed, Morgantown, WV, U.S.A. Photo 1 was taken looking upstream in the channel. Photo 2 was taken from the right bank looking downstream.

APPENDIX 18: Site 18

Table A18-1. Streamflow measurements and stage collected at Site 18, West Run Watershed, Morgantown, WV, U.S.A. (Figure 2).

Date	Mean Depth of Cross-Section (m)	Stage(PT in cm)	Barometric Pressure (in cm)	Pressure Corrected Stage (cm)	Stilling Well Offset (cm)	P-Corrected Stage + Offset (cm)	P-Corrected Stage + Offset (m)	SonTec Discharge (m3/s)	Estimated Discharge (m3/s)
9/21/2017	0.2637	114.29	87.84	26.45	6	32.45	0.3245	0.0418	0.0007
9/28/2017	0.1158	111.9	85.49	26.41	6	32.41	0.3241	0.0233	0.0021
10/5/2017	0.1090	116.99	91.34	25.65	6	31.65	0.3165	0.0223	0.0294
10/8/2017	0.1435	109.84	81.69	28.15	6	34.15	0.3415	0.0521	0.0609
10/9/2017	0.1952	110.82	78.84	31.98	6	37.98	0.3798	0.1786	0.2020
10/9/2017	0.1724	110.87	80.9	29.97	6	35.97	0.3597	0.1151	0.1276
10/9/2017	0.1536	110.07	81.11	28.96	6	34.96	0.3496	0.0946	0.0905
10/10/2017	0.1098	115.27	88.5	26.77	6	32.77	0.3277	0.0466	0.0109
10/11/2017	0.1309	112.1	82.56	29.54	6	35.54	0.3554	0.0655	0.1117
10/23/2017	0.1117	106	80.29	25.71	6	31.71	0.3171	0.0283	0.0273
10/23/2017	0.1622	103.76	74.71	29.05	6	35.05	0.3505	0.0986	0.0938
10/24/2017	0.2372	109.22	75.74	33.48	6	39.48	0.3948	0.2460	0.2580
10/24/2017	0.2227	108.21	76.09	32.12	6	38.12	0.3812	0.2235	0.2072
10/29/2017	0.3028	113.19	71.65	41.54	6	47.54	0.4754	0.5503	0.5677
10/30/2017	0.2489	113.76	77.47	36.29	6	42.29	0.4229	0.3584	0.3644
11/3/2017	0.1732	117.29	88.52	28.77	6	34.77	0.3477	0.0887	0.0835
11/6/2017	0.3737	136.88	88.27	48.61	6	54.61	0.5461	0.8692	0.8508
11/7/2017	0.3496	134.8	86.54	48.26	6	54.26	0.5426	0.9298	0.8365
3/8/2018	0.2179	107.06	76.76	30.3	6.4	36.7	0.367	0.2563	0.1545
3/16/2018	0.1770	114.48	86.64	27.84	6.4	34.24	0.3424	0.1370	0.0642
3/23/2018	0.1947	117.93	88.41	29.52	6.4	35.92	0.3592	0.1998	0.1257
3/30/2018	0.3923	138.1	85.78	52.32	6.4	58.72	0.5872	1.2084	1.0203
4/5/2018	0.2957	130.64	88.78	41.86	6.4	48.26	0.4826	0.6417	0.5960
6/18/2018	0.2762	119.37	86.92	32.45	6.4	38.85	0.3885	0.1835	0.2344
6/21/2018	0.2670	110.57	78.91	31.66	6.4	38.06	0.3806	0.1581	0.2049
6/21/2018	0.2670	110.57	79.01	31.56	6.4	37.96	0.3796	0.1536	0.2012
6/21/2018	0.2612	110.53	78.96	31.57	6.4	37.97	0.3797	0.1607	0.2016
6/21/2018	0.2600	110.49	79.02	31.47	6.4	37.87	0.3787	0.1580	0.1979
6/22/2018	0.1204	115.04	78.17	36.87	6.4	43.27	0.4327	0.3875	0.4019
6/22/2018	0.1149	114.24	78.31	35.93	6.4	42.33	0.4233	0.3586	0.3659
6/22/2018	0.1119	113.58	78.16	35.42	6.4	41.82	0.4182	0.3505	0.3465
6/22/2018	0.1106	113.58	78.16	35.42	6.4	41.82	0.4182	0.3370	0.3465
6/27/2018	0.1079	118.05	81.22	36.83	6.4	43.23	0.4323	0.2937	0.4004
6/27/2018	0.1094	115.84	80.88	34.96	6.4	41.36	0.4136	0.3020	0.3290
6/27/2018	0.1100	114.42	80.59	33.83	6.4	40.23	0.4023	0.3240	0.2863
7/6/2018	0.1350	128.83	91.04	37.79	6.4	44.19	0.4419	0.4384	0.4373
7/6/2018	0.1177	127.17	91	36.17	6.4	42.57	0.4257	0.3728	0.3751
7/26/2018	0.1155	114.08	83.54	30.54	6.4	36.94	0.3694	0.1055	0.1633
9/20/2018	0.1649	121.06	88.35	32.71	6.4	39.11	0.3911	0.2043	0.2442
10/25/2018	0.1192	120.32	90.79	29.53	6.4	35.93	0.3593	0.0694	0.1261
11/1/2018	0.1893	108.99	77.32	31.67	6.4	38.07	0.3807	0.1721	0.2053
11/1/2018	0.1917	108.41	76.99	31.42	6.4	37.82	0.3782	0.1729	0.1960
11/13/2018	0.2429	123.54	86.42	37.12	6.4	43.52	0.4352	0.3341	0.4115
10/31/2019	0.3993	122.4	68.25	54.15	6.4	60.55	0.6055	1.2005	1.0969
12/10/2019	0.4880	153.85	80.9	72.95	6.4	79.35	0.7935	1.7393	1.9258
12/17/2019	0.6046	161.36	76.38	84.98	6.4	91.38	0.9138	2.5587	2.4960
1/4/2020	0.4296	135.09	73.82	61.27	6.4	67.67	0.6767	1.3566	1.4019
4/8/2020	0.4810	1051.6	988.36	63.2	6.4	69.6	0.696	1.4515	1.4865
4/30/2020	0.5810	1066.4	988.61	77.8	6.4	84.2	0.842	2.1604	2.1519
4/30/2020	0.5430	1060.8	987.36	73.4	6.4	79.8	0.798	1.9381	1.9466
4/30/2020	0.5270	1059	988.51	70.5	6.4	76.9	0.769	1.8271	1.8135
4/30/2020	0.5080	1056.6	988.64	68	6.4	74.4	0.744	1.7150	1.7002
4/30/2020	0.4930	1053.9	987.84	66.1	6.4	72.5	0.725	1.6176	1.6150

Table A18-2. Modeled streamflow at Site 18, West Run Watershed, Morgantown, WV, U.S.A.

Cross-Section Area (m ²)	A (Cross Section area of flow)	P (Wetted Perimeter)	RH=A/P Hydraulic Radius (m)	Observed Slope (m)	Calculated Slope using ArcGIS (m)	Roughness Coefficient (n)	Manning Discharge (m ³ /s) (Obs Slope)	Manning Discharge (m ³ /s) (Calc Slope)	Chezy Coefficient (C)	Chezy Discharge (m ³ /s) (Obs Slope)	Chezy Discharge (m ³ /s) (Calc Slope)	Dingman & Sharma Discharge (m ³ /s) (Obs. Slope)	Dingman & Sharma Discharge (m ³ /s) (Calc Slope)
9.35	0.395	2.2517	0.175571	0.01	0.017	0.088	0.140859767	0.183658666	8.503404607	0.140859767	0.183658666	0.15924322	0.177513244
9.35	0.395	2.2507	0.175364	0.01	0.017	0.088	0.140521917	0.183218164	8.501735051	0.140521917	0.183218164	0.158866777	0.177093613
9.35	0.383	2.2317	0.171422	0.01	0.017	0.088	0.134154945	0.174916648	8.46957739	0.134154945	0.174916648	0.151769384	0.169181933
9.35	0.459	3.487	0.131632	0.01	0.017	0.088	0.134969976	0.175979319	8.104833875	0.134969976	0.175979319	0.169078086	0.188476468
9.35	0.803	4.5054	0.178231	0.01	0.017	0.088	0.288993229	0.37680107	8.524737726	0.288993229	0.37680107	0.367841699	0.410044292
9.35	0.657	4.1548	0.15813	0.01	0.017	0.088	0.218319668	0.284654021	8.356412479	0.218319668	0.284654021	0.2771067	0.308899238
9.35	0.585	4.1172	0.142087	0.01	0.017	0.088	0.181012734	0.236011731	8.208736433	0.181012734	0.236011731	0.231703258	0.258286646
9.35	0.400	2.2596	0.177222	0.01	0.017	0.088	0.143572437	0.187195555	8.516681537	0.143572437	0.187195555	0.16226514	0.180881871
9.35	0.445	2.3237	0.191354	0.01	0.017	0.088	0.167786787	0.218767205	8.6262793	0.167786787	0.218767205	0.189188176	0.210893795
9.35	0.384	2.2333	0.171734	0.01	0.017	0.088	0.134653993	0.175567327	8.472147052	0.134653993	0.175567327	0.152325894	0.169802292
9.35	0.437	2.3128	0.188872	0.01	0.017	0.088	0.163407696	0.213057569	8.607529708	0.163407696	0.213057569	0.184326466	0.2054743
9.35	0.977	4.5362	0.215379	0.01	0.017	0.088	0.39891479	0.520121251	8.798008747	0.39891479	0.520121251	0.499417803	0.556716164
9.35	0.921	4.4952	0.204885	0.01	0.017	0.088	0.363734112	0.474251259	8.725073545	0.363734112	0.474251259	0.456791001	0.509198776
9.35	0.636	2.5253	0.251908	0.01	0.017	0.088	0.288337124	0.375945614	9.030761931	0.288337124	0.375945614	0.321442789	0.358322021
9.35	0.552	2.4523	0.22524	0.01	0.017	0.088	0.232365864	0.30296802	8.863898451	0.232365864	0.30296802	0.260450264	0.290331805
9.35	0.432	2.3065	0.187451	0.01	0.017	0.088	0.160923844	0.209819023	8.596700647	0.160923844	0.209819023	0.181567399	0.202398684
9.35	1.686	5.2584	0.32063	0.01	0.017	0.088	0.897520132	1.17022308	9.401229464	0.897520132	1.17022308	1.110560593	1.237975559
9.35	0.743	2.5841	0.287677	0.01	0.017	0.088	0.368128087	0.479980303	9.232830414	0.368128087	0.479980303	0.406939565	0.456327869
9.35	0.463	2.3486	0.197207	0.01	0.017	0.088	0.178318112	0.232498372	8.669707128	0.178318112	0.232498372	0.200866153	0.22391159
9.35	0.424	2.2944	0.184754	0.01	0.017	0.088	0.15625904	0.203736861	8.57596377	0.15625904	0.203736861	0.176382912	0.196619378
9.35	0.451	2.3320	0.193274	0.01	0.017	0.088	0.171211199	0.223232092	8.640649963	0.171211199	0.223232092	0.192987641	0.215129173
9.35	0.815	2.6016	0.313092	0.01	0.017	0.088	0.426793659	0.556470849	9.364024627	0.426793659	0.556470849	0.468612798	0.522376891
9.35	0.648	2.5335	0.255632	0.01	0.017	0.088	0.296431019	0.386498762	9.052877665	0.296431019	0.386498762	0.3301962	0.368079713
9.35	1.599	6.3432	0.252081	0.01	0.017	0.088	0.725090972	0.945402961	9.031793601	0.725090972	0.945402961	0.947909815	1.056663806
9.35	1.505	6.1728	0.243812	0.01	0.017	0.088	0.6674571	0.870257586	8.981724097	0.6674571	0.870257586	0.871181774	0.971132732
9.35	1.505	6.1728	0.243812	0.01	0.017	0.088	0.6674571	0.870257586	8.981724097	0.6674571	0.870257586	0.871181774	0.971132732
9.35	1.474	6.1616	0.239224	0.01	0.017	0.088	0.645481995	0.841605555	8.953331367	0.645481995	0.841605555	0.84373466	0.940536602
9.35	1.466	6.1588	0.238033	0.01	0.017	0.088	0.639847599	0.834259201	8.945891765	0.639847599	0.834259201	0.836694749	0.932689001
9.35	0.826	7.0988	0.116358	0.01	0.017	0.088	0.223714489	0.291688007	9.739927051	0.223714489	0.291688007	0.230606547	0.357389837
9.35	0.787	7.0876	0.111039	0.01	0.017	0.088	0.206605755	0.269380948	7.878252876	0.206605755	0.269380948	0.297307129	0.331417269
9.35	0.75	6.9298	0.108228	0.01	0.017	0.088	0.193555552	0.252365564	7.844659331	0.193555552	0.252365564	0.278112069	0.310019954
9.35	0.741	6.927	0.106973	0.01	0.017	0.088	0.189751062	0.247405116	7.829418323	0.189751062	0.247405116	0.27292462	0.304237348
9.35	1.219	5.663	0.215257	0.01	0.017	0.088	0.497537473	0.648709498	8.797180817	0.497537473	0.648709498	0.647294554	0.721558861
9.35	1.178	5.34	0.220599	0.01	0.017	0.088	0.488725846	0.637220542	8.833198705	0.488725846	0.637220542	0.627959721	0.700005737
9.35	1.19	5.691	0.209102	0.01	0.017	0.088	0.476397938	0.621146917	8.754749494	0.476397938	0.621146917	0.622009023	0.693372314
9.35	0.947	7.2802	0.130079	0.01	0.017	0.088	0.276272985	0.360215901	8.088818785	0.276272985	0.360215901	0.393530087	0.438679918
9.35	0.815	7.1692	0.113681	0.01	0.017	0.088	0.217336605	0.283372263	7.909186443	0.217336605	0.283372263	0.312679486	0.348553301
9.35	0.519	4.727	0.109795	0.01	0.017	0.088	0.135229836	0.176318135	7.863470957	0.135229836	0.176318135	0.181618783	0.202455963
9.35	0.804	5.2066	0.154419	0.01	0.017	0.088	0.262971046	0.342872295	8.323403849	0.262971046	0.342872295	0.347842647	0.387750744
9.35	0.535	4.7292	0.113127	0.01	0.017	0.088	0.142205102	0.185412768	7.902751843	0.142205102	0.185412768	0.190468068	0.212320529
9.35	0.909	5.1798	0.175489	0.01	0.017	0.088	0.323778847	0.422155968	8.502744775	0.323778847	0.422155968	0.422797626	0.471305331
9.35	0.92	5.1842	0.177462	0.01	0.017	0.088	0.330148409	0.43046086	8.518602259	0.330148409	0.43046086	0.430727204	0.480144672
9.35	1.185	5.363	0.220958	0.01	0.017	0.088	0.492163475	0.641702662	8.835594037	0.492163475	0.641702662	0.632750643	0.705346323
9.35	2.404	6.8186	0.352565	0.01	0.017	0.088	1.363362331	1.777606998	9.551183803	1.363362331	1.777606998	1.748914482	1.94956799
9.35	3.533	8.215	0.430067	0.01	0.017	0.088	2.287450361	2.982470379	9.872792426	2.287450361	2.982470379	2.974566368	3.315839303
9.35	4.515	8.6772	0.520329	0.01	0.017	0.088	3.3191523	4.327645131	10.19131798	3.3191523	4.327645131	4.280175273	4.771241128
9.35	2.816	7.4122	0.379914	0.01	0.017	0.088	1.678573358	2.188591895	9.670855957	1.678573358	2.188591895	2.169352148	2.418242602
9.35	3.26206	7.744	0.421237	0.01	0.017	0.088	2.083021119	2.715927258	9.838716076	2.083021119	2.715927258	2.686417082	2.994630558
9.35	4.29328	8.553	0.501962	0.01	0.017	0.088	3.081439902	4.017706084	10.13045888	3.081439902	4.017706084	3.977102577	4.433396806
9.35	3.97393	8.401	0.473031	0.01	0.017	0.088	2.741555399	3.57455091	10.03072212	2.741555399	3.57455091	3.547135262	3.954099205
9.35	3.77186	8.217	0.459031	0.01	0.017	0.088	2.550553343	3.325514698	9.980624293	2.550553343	3.325514698	3.296653764	3.674879887
9.35	3.63715	8.179	0.444694	0.01	0.017	0.088	2.407978155	3.139619396	9.927978512	2.407978155	3.139619396	3.11913414	3.47699338
9.35	3.49548	8.073	0.432984	0.01	0.017	0.088	2.273380142	2.964125058	9.883921922	2.273380142	2.964125058	2.945499803	3.283437922

Figure A18-1. Observed and modeled rating curves and streamflow from Site 18, West Run Watershed, Morgantown, West Virginia, U.S.A.

Table A18-3. Polynomial rating equations and R^2 values for observed and modeled rating curves at Site 18, West Run Watershed, Morgantown, WV, U.S.A.

	R² Value	Polynomial Equation
Observed Curve	0.99	$y = 1.0725x^2 + 2.9085x - 1.0574$
Manning's Curve (Obs Slope)	0.94	$y = 8.2173x^2 - 4.167x + 0.6718$
Manning's Curve (Calc Slope)	0.94	$y = 10.714x^2 - 5.4331x + 0.8759$
Chezy's Curve (Obs Slope)	0.94	$y = 8.2173x^2 - 4.167x + 0.6718$
Chezy's Curve (Calc Slope)	0.94	$y = 10.714x^2 - 5.4331x + 0.8759$
Dingman and Sharma's Curve (Obs Slope)	0.93	$y = 10.727x^2 - 5.5025x + 0.8895$
Dingman and Sharma's Curve (Calc Slope)	0.93	$y = 11.957x^2 - 6.1338x + 0.9915$

Table A18-4. Descriptive statistics for observed and modeled streamflow used to generate the rating curves for Site 18, West Run Watershed, Morgantown, WV, U.S.A.

	Sample Size	Mean (m³/s)	St. Dev.	SE of Mean
Observed	53	0.549	0.651	0.089
Manning's Curve (Obs Slope)	53	0.705	0.869	0.119
Manning's Curve (Calc Slope)	53	0.919	1.133	0.156
Chezy's Curve (Obs Slope)	53	0.705	0.869	0.119
Chezy's Curve (Calc Slope)	53	0.919	1.133	0.156
Dingman and Sharma's Curve (Obs Slope)	53	0.904	1.127	0.155
Dingman and Sharma's Curve (Calc Slope)	53	1.008	1.257	0.173

Table A18-5. P-values of the statistical analyses (post-hoc ANOVA) for observed and modeled rating curves at Site 18, West Run Watershed, Morgantown, WV, U.S.A.

	Observed Curve	Rating Equation Curve	Manning's Curve (Obs Slope)	Manning's Curve (Calc Slope)	Chezy's Curve (Obs Slope)	Chezy's Curve (Calc Slope)	Dingman and Sharma's Curve (Obs Slope)	Dingman and Sharma's Curve (Calc Slope)
Observed Curve	-	1	0.99	0.53	0.99	0.53	0.58	0.25
Rating Equation Curve	-	-	0.99	0.53	0.99	0.53	0.58	0.25
Manning's Curve (Obs Slope)	-	-	-	0.95	1	0.95	0.97	0.76
Manning's Curve (Calc Slope)	-	-	-	-	0.95	1	1	1
Chezy's Curve (Obs Slope)	-	-	-	-	-	0.95	0.97	0.76
Chezy's Curve (Calc Slope)	-	-	-	-	-	-	1	1
Dingman and Sharma's Curve (Obs Slope)	-	-	-	-	-	-	-	1
Dingman and Sharma's Curve (Calc Slope)	-	-	-	-	-	-	-	-

Figure A18-2. Box and whisker plots for the results of the statistical analyses (post-hoc ANOVA) of observed and modeled rating curves at Site 18, West Run Watershed, Morgantown, WV, U.S.A.

Figure A18-3. Cross-sectional profile of WRW Site 18, plotting the stream channel's shape, water surface, and bankfull. The profile is created with a Channel Width of 0= Left Bank facing downstream.

Figure A18-4. Plan view profile of WRW Site 18, West Run Watershed, Morgantown, WV, U.S.A. (Figure 2). Showing the positioning of stilling well in relation to where the streamflow was measured. Along with the channel width at the stilling well, point where cross-sections were performed, and 25.5m upstream and downstream from the stilling well.

Figure A18-5. Photographs showing channel characteristics at Site #18, West Run Watershed, Morgantown, WV, U.S.A. Photo 1 was taken looking upstream in the channel. Photo 2 was taken from the right bank looking upstream.

APPENDIX 19: Site 19

Table A19-1. Streamflow measurements and stage collected at Site 19, West Run Watershed, Morgantown, WV, U.S.A. (Figure 2).

Date	Mean Depth of Cross-Section (m)	Stage(PT in cm)	Barometric Pressure (in cm)	Pressure Corrected Stage (cm)	Stilling Well Offset (cm)	P-Corrected Stage + Offset (cm)	P-Corrected Stage + Offset (m)	SonTec Discharge (m ³ /s)	Rating Equation Discharge (m ³ /s)
10/25/2018	0.1445	110.38	89.9	20.48	5.4	25.88	0.2588	0.0761	0.186297134
10/25/2018	0.1417	110.43	90.38	20.05	5.4	25.45	0.2545	0.0735	0.174754214
10/30/2018	0.1798	115.93	88.99	26.94	5.4	32.34	0.3234	0.3506	0.397006917
10/30/2018	0.1777	115	89.27	25.73	5.4	31.13	0.3113	0.3240	0.3522164
11/1/2018	0.1649	99.77	76.96	22.81	5.4	28.21	0.2821	0.1878	0.254232472
11/13/2018	0.1841	112.61	86.07	26.54	5.4	31.94	0.3194	0.3572	0.381928632
11/29/2018	0.1646	109.53	86.11	23.42	5.4	28.82	0.2882	0.2130	0.273520933
1/15/2019	0.1658	112.74	89.6	23.14	5.4	28.54	0.2854	0.1757	0.264589785
1/15/2019	0.1762	112.54	89.33	23.21	5.4	28.61	0.2861	0.1825	0.266810254
1/29/2019	0.1768	102.37	75.46	26.91	5.4	32.31	0.3231	0.3986	0.395866744
3/19/2019	0.1597	115.41	96.42	18.99	5.4	24.39	0.2439	0.1853	0.147623064
3/20/2019	0.1506	104.49	87.26	17.23	5.4	22.63	0.2263	0.1390	0.106734129
4/2/2019	0.1655	104.08	87.19	16.89	5.4	22.29	0.2229	0.1001	0.09943344
4/23/2019	0.1643	103.11	83.79	19.32	5.4	24.72	0.2472	0.2409	0.155867687
4/23/2019	0.1664	102.89	83.93	18.96	5.4	24.36	0.2436	0.2262	0.146882603
4/25/2019	0.1369	99.59	78.24	21.35	5.4	26.75	0.2675	0.2572	0.210599158
4/25/2019	0.1305	99.29	77.75	21.54	5.4	26.94	0.2694	0.2455	0.216075264
4/30/2019	0.1475	109.99	91.08	18.91	5.4	24.31	0.2431	0.1999	0.145651853
4/30/2019	0.1478	110.09	91.04	19.05	5.4	24.45	0.2445	0.1982	0.149108511
5/15/2019	0.1320	106.03	84.32	21.71	5.4	27.11	0.2711	0.2865	0.221026221
4/8/2020	0.2500	1033.8	989.01	44.8	5.4	50.20	0.502	1.4547	1.343534119
4/8/2020	0.2410	1032.9	989.07	43.8	5.4	49.20	0.492	1.3286	1.276408901
4/8/2020	0.2320	1031.9	989.31	42.6	5.4	48.00	0.48	1.2676	1.19807088
4/8/2020	0.2270	1031.6	989.23	42.4	5.4	47.80	0.478	1.2070	1.185249175
4/8/2020	0.2150	1031.5	989.57	41.9	5.4	47.30	0.473	1.0553	1.153488201
8/10/2021	0.3180	1945.3	1001.96	43.3	5.4	48.70	0.487	1.4569	1.243474769
8/10/2021	0.3520	1054.9	1001.64	53.3	5.4	58.70	0.587	2.0810	1.981764549
8/10/2021	0.3380	1054.5	1002.25	52.2	5.4	57.60	0.576	1.8514	1.892348947
8/10/2021	0.3270	1054.4	1002.11	52.3	5.4	57.70	0.577	1.9042	1.900393841
8/10/2021	0.3160	1052.2	1001.78	50.4	5.4	55.80	0.558	1.5265	1.750406711
8/10/2021	0.3050	1051.5	1001.69	49.8	5.4	55.20	0.552	1.6234	1.704299309

Table A19-2. Modeled streamflow at Site 19, West Run Watershed, Morgantown, WV, U.S.A.

Cross-Section Area (m ²)	A (Cross Section area of flow)	P (Wetted Perimeter)	RH=A/P Hydraulic Radius (m)	Observed Slope (m)	Calculated Slope using ArcGIS (m)	Roughness Coefficient (n)	Manning Discharge (m ³ /s) (Obs Slope)	Manning Discharge (m ³ /s) (Calc Slope)	Chezy Coefficient (C)	Chezy Discharge (m ³ /s) (Obs Slope)	Chezy Discharge (m ³ /s) (Calc Slope)	Dingman & Sharma Discharge (m ³ /s) (Obs. Slope)	Dingman & Sharma Discharge (m ³ /s) (Calc Slope)
15.51	0.826	6.0042	0.13757	0.015	0.011	0.135	0.19969867	0.171011724	5.322149229	0.19969867	0.171011724	0.372930225	0.349914355
15.51	0.824	5.9997	0.13734	0.015	0.011	0.135	0.198992874	0.170407316	5.320664125	0.198992874	0.170407316	0.371622259	0.348687111
15.51	1.26	7.3694	0.170977	0.015	0.011	0.135	0.352134046	0.301549581	5.518520167	0.352134046	0.301549581	0.66759034	0.626389141
15.51	1.2	7.3687	0.162851	0.015	0.011	0.135	0.324653449	0.278016604	5.473913873	0.324653449	0.278016604	0.618295063	0.580136185
15.51	1.081	6.883	0.157054	0.015	0.011	0.135	0.285475935	0.244466986	5.440943535	0.285475935	0.244466986	0.53913402	0.505860668
15.51	1.319	7.5314	0.175133	0.015	0.011	0.135	0.374572633	0.32076484	5.540654613	0.374572633	0.32076484	0.711205009	0.667312074
15.51	1.142	7.2632	0.157231	0.015	0.011	0.135	0.301812136	0.258456472	5.441967139	0.301812136	0.258456472	0.5752513	0.539748924
15.51	0.973	6.1986	0.156971	0.015	0.011	0.135	0.256864559	0.219965667	5.44046603	0.256864559	0.219965667	0.476413524	0.447011049
15.51	0.974	6.1988	0.157127	0.015	0.011	0.135	0.257299163	0.220337839	5.441368276	0.257299163	0.220337839	0.477177786	0.447728143
15.51	1.308	7.7448	0.168888	0.015	0.011	0.135	0.362563958	0.310481225	5.507220784	0.362563958	0.310481225	0.694096616	0.651259548
15.51	0.924	6.1102	0.151223	0.015	0.011	0.135	0.237936752	0.203756861	5.406742117	0.237936752	0.203756861	0.441753368	0.414489989
15.51	0.872	6.092	0.143139	0.015	0.011	0.135	0.216470842	0.185374554	5.357460732	0.216470842	0.185374554	0.403764844	0.378845975
15.51	0.782	5.0552	0.154692	0.015	0.011	0.135	0.204439223	0.175071291	5.427222582	0.204439223	0.175071291	0.366537923	0.343916562
15.51	0.926	5.9674	0.155176	0.015	0.011	0.135	0.242590285	0.207741909	5.43005053	0.242590285	0.207741909	0.447471161	0.419854901
15.51	0.926	5.9674	0.155176	0.015	0.011	0.135	0.242590285	0.207741909	5.43005053	0.242590285	0.207741909	0.447471161	0.419854901
15.51	1.012	7.6648	0.132032	0.015	0.011	0.135	0.238055835	0.203858838	5.285825792	0.238055835	0.203858838	0.46553104	0.436800192
15.51	0.974	7.7288	0.126022	0.015	0.011	0.135	0.222110323	0.190203917	5.244942275	0.222110323	0.190203917	0.436876255	0.409913873
15.51	0.854	6.086	0.140322	0.015	0.011	0.135	0.209212203	0.179158627	5.33974542	0.209212203	0.179158627	0.390886328	0.366762273
15.51	0.845	6.0106	0.140585	0.015	0.011	0.135	0.207265885	0.1774919	5.341411599	0.207265885	0.1774919	0.386347851	0.362503895
15.51	0.985	7.7318	0.127396	0.015	0.011	0.135	0.22624822	0.1937474	5.254428677	0.22624822	0.1937474	0.444593362	0.417154709
15.51	2.05896	8.73	0.235849	0.015	0.011	0.135	0.713042716	0.610613302	5.822442064	0.713042716	0.610613302	1.350711175	1.267350291
15.51	1.96664	8.635	0.227752	0.015	0.011	0.135	0.665393284	0.569808766	5.788641483	0.665393284	0.569808766	1.262188763	1.184291155
15.51	1.88117	8.564	0.21966	0.015	0.011	0.135	0.621308787	0.532057058	5.753844611	0.621308787	0.532057058	1.18087704	1.10799769
15.51	1.81846	8.478	0.214492	0.015	0.011	0.135	0.591138403	0.506220684	5.731055597	0.591138403	0.506220684	1.124078565	1.054704606
15.51	1.72219	8.431	0.204269	0.015	0.011	0.135	0.541910509	0.464064435	5.684599779	0.541910509	0.464064435	1.034198504	0.970371609
15.51	2.56529	8.7713	0.292464	0.015	0.011	0.135	1.025407913	0.878106875	6.035014465	1.025407913	0.878106875	1.905224278	1.787640903
15.51	2.8138	8.705	0.32324	0.015	0.011	0.135	1.20232364	1.029608453	6.136493895	1.20232364	1.029608453	2.210195864	2.073790774
15.51	2.73019	8.753	0.311915	0.015	0.011	0.135	1.139187895	0.975542231	6.100127167	1.139187895	0.975542231	2.103142232	1.973344095
15.51	2.62538	8.693	0.302011	0.015	0.011	0.135	1.07214213	0.918127668	6.06740959	1.07214213	0.918127668	1.982994201	1.860611155
15.51	2.51941	8.595	0.293125	0.015	0.011	0.135	1.008585426	0.863700958	6.03728567	1.008585426	0.863700958	1.867001924	1.751777491
15.51	2.41316	8.535	0.282737	0.015	0.011	0.135	0.943089785	0.807613842	6.001088022	0.943089785	0.807613842	1.7495509	1.641575108

Figure A19-1. Observed and modeled rating curves and streamflow from Site 19, West Run Watershed, Morgantown, West Virginia, U.S.A.

Table A19-3. Polynomial rating equations and R^2 values for observed and modeled rating curves at Site 19, West Run Watershed, Morgantown, WV, U.S.A.

	R² Value	Polynomial Equation
Observed Curve	0.98	$y = 8.3797x^2 - 1.6169x + 0.0435$
Manning's Curve (Obs Slope)	0.95	$y = 6.2508x^2 - 2.5353x + 0.4757$
Manning's Curve (Calc Slope)	0.95	$y = 5.3528x^2 - 2.1711x + 0.4074$
Chezy's Curve (Obs Slope)	0.95	$y = 6.2508x^2 - 2.5353x + 0.4757$
Chezy's Curve (Calc Slope)	0.95	$y = 5.3528x^2 - 2.1711x + 0.4074$
Dingman and Sharma's Curve (Obs Slope)	0.95	$y = 10.387x^2 - 3.7392x + 0.7198$
Dingman and Sharma's Curve (Calc Slope)	0.95	$y = 9.7462x^2 - 3.5084x + 0.6754$

Table A19-4. Descriptive statistics for observed and modeled streamflow used to generate the rating curves for Site 19, West Run Watershed, Morgantown, WV, U.S.A.

	Sample Size	Mean (m³/s)	St. Dev.	SE of Mean
Observed	31	0.683	0.663	0.119
Manning's Curve (Obs Slope)	31	0.474	0.33	0.059
Manning's Curve (Calc Slope)	31	0.406	0.283	0.051
Chezy's Curve (Obs Slope)	31	0.474	0.33	0.059
Chezy's Curve (Calc Slope)	31	0.406	0.283	0.051
Dingman and Sharma's Curve (Obs Slope)	31	0.887	0.609	0.109
Dingman and Sharma's Curve (Calc Slope)	31	0.833	0.571	0.103

Table A19-5. P-values of the statistical analyses (post-hoc ANOVA) for observed and modeled rating curves at Site 19, West Run Watershed, Morgantown, WV, U.S.A.

	Observed Curve	Rating Equation Curve	Manning's Curve (Obs Slope)	Manning's Curve (Calc Slope)	Chezy's Curve (Obs Slope)	Chezy's Curve (Calc Slope)	Dingman and Sharma's Curve (Obs Slope)	Dingman and Sharma's Curve (Calc Slope)
Observed Curve	-	1	0.71	0.35	0.71	0.35	0.73	0.93
Rating Equation Curve	-	-	0.71	0.35	0.71	0.35	0.73	0.93
Manning's Curve (Obs Slope)	-	-	-	1	1	0.95	0.02*	0.08
Manning's Curve (Calc Slope)	-	-	-	-	1	1	<0.05*	0.02*
Chezy's Curve (Obs Slope)	-	-	-	-	-	1	0.02*	0.08
Chezy's Curve (Calc Slope)	-	-	-	-	-	-	<0.05*	0.02*
Dingman and Sharma's Curve (Obs Slope)	-	-	-	-	-	-	-	1
Dingman and Sharma's Curve (Calc Slope)	-	-	-	-	-	-	-	-

*= indicates that the difference of the means is significant at the 0.05 level.

Figure A19-2. Box and whisker plots for the results of the statistical analyses (post-hoc ANOVA) of observed and modeled rating curves at Site 19, West Run Watershed, Morgantown, WV, U.S.A

Figure A19-3. Cross-sectional profile of WRW Site 19, plotting the stream channel's shape, water surface, and bankfull. The profile is created with a Channel Width of 0= Left Bank facing downstream.

Figure A19-4. Plan view profile of WRW Site 19, West Run Watershed, Morgantown, WV, U.S.A. (Figure 2). Showing the positioning of stilling well in relation to where the streamflow was measured. Along with the channel width at the stilling well, point where cross-sections were performed, and 6.0m upstream and downstream from the stilling well.

Figure A19-5. Photographs showing channel characteristics at Site #19, West Run Watershed, Morgantown, WV, U.S.A. Photo 1 was taken looking upstream in the channel. Photo 2 was taken from the left bank looking downstream.

APPENDIX 20: Site 20

Table A20-1. Streamflow measurements and stage collected at Site 20, West Run Watershed, Morgantown, WV, U.S.A. (Figure 2).

Date	Mean Depth of Cross-Section (m)	Stage(PT in cm)	Barometric Pressure (in cm)	Pressure Corrected Stage (cm)	Stilling Well Offset (cm)	P-Corrected Stage + Offset (cm)	P-Corrected Stage + Offset (m)	SonTec Discharge (m3/s)	Rating Equation Discharge (m3/s)
12/8/2017	0.0953	118.01	87.7	30.31	3.4	33.71	0.3371	0.0115	0.02585634
1/12/2018	0.2022	122.41	73.53	48.88	3.4	52.28	0.5228	0.4135	0.344404025
2/1/2018	0.1082	111.67	80.55	31.12	3.4	34.52	0.3452	0.0231	0.026526594
3/23/2018	0.1101	119.13	88.07	31.06	3.4	34.46	0.3446	0.0239	0.026435578
3/28/2018	0.1556	124.93	82.54	42.39	3.4	45.79	0.4579	0.2313	0.161004481
4/2/2018	0.1480	128.67	85.85	42.82	3.4	46.22	0.4622	0.2076	0.1707603
4/5/2018	0.1368	125.44	89.91	35.53	3.4	38.93	0.3893	0.0841	0.051337766
10/25/2018	0.0710	119.23	89.99	29.24	3.4	32.64	0.3264	0.0091	0.026820166
10/30/2018	0.1186	122.25	88.27	33.98	3.4	37.38	0.3738	0.0321	0.038542118
10/30/2018	0.1207	122.14	88.55	33.59	3.4	36.99	0.3699	0.0306	0.036018095
11/1/2018	0.0927	107.37	76.93	30.44	3.4	33.84	0.3384	0.0114	0.025882647
11/13/2018	0.1616	122.49	86.2	36.29	3.4	39.69	0.3969	0.0653	0.059225649
11/29/2018	0.1058	117.71	85.97	31.74	3.4	35.14	0.3514	0.0143	0.027854662
1/15/2019	0.1125	122.14	89.69	32.45	3.4	35.85	0.3585	0.0176	0.03024359
1/15/2019	0.1085	122.41	89.96	32.45	3.4	35.85	0.3585	0.0183	0.03024359
1/29/2019	0.1868	113.39	75.48	37.91	3.4	41.31	0.4131	0.0797	0.07958367
3/19/2019	0.0866	127.26	95.69	31.57	3.4	34.97	0.3497	0.0160	0.027420189
3/20/2019	0.0780	117.38	87.68	29.7	3.4	33.1	0.331	0.0070	0.026147861
4/2/2019	0.0847	117.22	86.96	30.26	3.4	33.66	0.3366	0.0076	0.025854495
4/23/2019	0.0908	111.37	83.52	27.85	3.4	31.25	0.3125	0.0138	0.031215625
4/23/2019	0.0921	111.19	83.49	27.7	3.4	31.1	0.311	0.0139	0.031902309
4/25/2019	0.1728	114.14	78.77	35.37	3.4	38.77	0.3877	0.0871	0.049812477
4/25/2019	0.1811	116.62	78.66	37.96	3.4	41.36	0.4136	0.0990	0.080288764
4/26/2019	0.1716	106.71	69.53	37.18	3.4	40.58	0.4058	0.0882	0.069812738
4/30/2019	0.0893	117.71	90.46	27.25	3.4	30.65	0.3065	0.0128	0.034210566
4/30/2019	0.0872	117.93	90.71	27.22	3.4	30.62	0.3062	0.0135	0.034377687
5/13/2019	0.1500	109.72	75.03	34.69	3.4	38.09	0.3809	0.0636	0.043855091
5/14/2019	0.2298	125.67	81.13	44.54	3.4	47.94	0.4794	0.2524	0.213183077
5/14/2019	0.2121	123.89	81.21	42.68	3.4	46.08	0.4608	0.2103	0.167546664
5/15/2019	0.1219	114.85	84.27	30.58	3.4	33.98	0.3398	0.0268	0.025945727
7/21/2020	0.2750	1074.7	1001.39	73.3	3.4	76.7	0.767	2.0314	1.728376619
7/21/2020	0.2860	1067.6	1001.06	66.5	3.4	69.9	0.699	1.3820	1.232850773
7/21/2020	0.2670	1065.6	1001.23	64.4	3.4	67.8	0.678	1.0757	1.097002075
7/21/2020	0.2560	1062.6	1001.40	61.2	3.4	64.6	0.646	0.8295	0.905585525
7/26/2021	0.3110	1078.9	999.98	78.9	3.4	82.3	0.823	2.2885	2.200291531
7/26/2021	0.2540	1067.6	999.75	67.9	3.4	71.3	0.713	1.3516	1.327921043
7/26/2021	0.2330	1062.3	999.69	62.6	3.4	66	0.66	1.0829	0.98701368
7/26/2021	0.1980	1057.9	999.38	58.5	3.4	61.9	0.619	0.9513	0.758721941
9/9/2021	0.1770	1054.4	996.19	58.2	3.4	61.6	0.616	0.6279	0.743231117
9/9/2021	0.2540	1063.1	995.93	67.2	3.4	70.6	0.706	1.2630	1.279935461
9/9/2021	0.2740	1068.7	995.51	73.2	3.4	76.6	0.766	1.3765	1.720473557
9/9/2021	0.2430	1064.8	995.74	69.1	3.4	72.5	0.725	1.1076	1.412278
9/22/2021	0.3850	1076.4	991.19	85.2	3.4	88.6	0.886	3.0483	2.800114229
9/22/2021	0.3670	1074	991.81	82.2	3.4	85.6	0.856	2.5765	2.505383501
9/22/2021	0.3340	1072.2	991.92	80.3	3.4	83.7	0.837	2.1401	2.327279203
9/22/2021	0.3140	1068.5	992.07	76.4	3.4	79.8	0.798	1.7689	1.982490811

Table A20-2. Modeled streamflow at Site 20, West Run Watershed, Morgantown, WV, U.S.A.

Cross-Section Area (m ²)	A (Cross Section area of flow)	P (Wetted Perimeter)	RH=A/P Hydraulic Radius (m)	Observed Slope (m)	Calculated Slope using ArcGIS (m)	Roughness Coefficient (n)	Manning Discharge (m ³ /s) (Obs Slope)	Manning Discharge (m ³ /s) (Calc Slope)	Chezy Coefficient (C)	Chezy Discharge (m ³ /s) (Obs Slope)	Chezy Discharge (m ³ /s) (Calc Slope)	Dingman & Sharma Discharge (m ³ /s) (Obs. Slope)	Dingman & Sharma Discharge (m ³ /s) (Calc Slope)
5.63	0.415	2.2821	0.182048	0.03	0.011	0.11	0.210121766	0.127235048	6.843919932	0.210121766	0.127235048	0.2112983	0.174792917
5.63	0.712	2.5708	0.276873	0.03	0.011	0.11	0.476105441	0.288296161	7.339289577	0.476105441	0.288296161	0.469919119	0.38873258
5.63	0.428	2.3008	0.18618	0.03	0.011	0.11	0.219925379	0.13317143	6.869567006	0.219925379	0.13317143	0.221005576	0.182823095
5.63	0.427	2.2995	0.185874	0.03	0.011	0.11	0.219193848	0.132728467	6.867688195	0.219193848	0.132728467	0.220281584	0.182224186
5.63	0.608	2.5036	0.242936	0.03	0.011	0.11	0.372866918	0.225782132	7.181070429	0.372866918	0.225782132	0.370854372	0.306782957
5.63	0.615	2.5092	0.245131	0.03	0.011	0.11	0.379341763	0.229702844	7.191844875	0.379341763	0.229702844	0.377121521	0.311967349
5.63	0.499	2.3932	0.208401	0.03	0.011	0.11	0.276044622	0.16715332	6.999878894	0.276044622	0.16715332	0.276361518	0.228615355
5.63	0.314	4.5618	0.068832	0.03	0.011	0.11	0.083041119	0.050283895	5.819775287	0.083041119	0.050283895	0.103115088	0.085300199
5.63	0.525	4.5848	0.114509	0.03	0.011	0.11	0.194933517	0.118038106	6.335007492	0.194933517	0.118038106	0.230987673	0.191080615
5.63	0.518	4.5824	0.113041	0.03	0.011	0.11	0.190687494	0.115467012	6.321402474	0.190687494	0.115467012	0.226209006	0.187127544
5.63	0.402	4.5282	0.088777	0.03	0.011	0.11	0.125968212	0.07627754	6.071892262	0.125968212	0.07627754	0.152539992	0.126186108
5.63	0.764	5.0472	0.151371	0.03	0.011	0.11	0.341682863	0.206899248	6.636632796	0.341682863	0.206899248	0.401044002	0.331756814
5.63	0.46	4.5546	0.100997	0.03	0.011	0.11	0.157083596	0.095118841	6.203811305	0.157083596	0.095118841	0.188124064	0.155622425
5.63	0.489	4.5682	0.107044	0.03	0.011	0.11	0.173587841	0.105112658	6.26423353	0.173587841	0.105112658	0.206866978	0.171127181
5.63	0.48	4.6374	0.103506	0.03	0.011	0.11	0.166617379	0.100891834	6.229240446	0.166617379	0.100891834	0.199705038	0.165202589
5.63	0.868	5.0216	0.172853	0.03	0.011	0.11	0.424104363	0.256807945	6.785058291	0.424104363	0.256807945	0.491203056	0.406339354
5.63	0.382	4.5928	0.083174	0.03	0.011	0.11	0.114609827	0.069399697	6.006271409	0.114609827	0.069399697	0.139978403	0.115794748
5.63	0.363	4.8042	0.075559	0.03	0.011	0.11	0.102156247	0.06185868	5.910917609	0.102156247	0.06185868	0.126879386	0.104958809
5.63	0.375	4.5898	0.081703	0.03	0.011	0.11	0.111179371	0.067322453	5.988438115	0.111179371	0.067322453	0.13600036	0.112503979
5.63	0.407	4.6042	0.088398	0.03	0.011	0.11	0.127171317	0.077006057	6.067559162	0.127171317	0.077006057	0.154502927	0.127809913
5.63	0.407	4.6042	0.088398	0.03	0.011	0.11	0.127171317	0.077006057	6.067559162	0.127171317	0.077006057	0.154502927	0.127809913
5.63	0.816	5.0694	0.160966	0.03	0.011	0.11	0.380201506	0.230223445	6.704960873	0.380201506	0.230223445	0.444030062	0.367316299
5.63	0.856	5.0864	0.168292	0.03	0.011	0.11	0.410850553	0.248782365	6.754883406	0.410850553	0.248782365	0.478105133	0.395504321
5.63	0.81	5.067	0.159858	0.03	0.011	0.11	0.375672182	0.227480803	6.697247271	0.375672182	0.227480803	0.438988306	0.363145593
5.63	0.402	4.6748	0.085993	0.03	0.011	0.11	0.123320707	0.074674397	6.039734081	0.123320707	0.074674397	0.150608244	0.124588103
5.63	0.391	4.6704	0.083719	0.03	0.011	0.11	0.117822026	0.07134478	6.012813887	0.117822026	0.07134478	0.144231057	0.119312683
5.63	0.709	5.0242	0.141117	0.03	0.011	0.11	0.302598698	0.183232611	6.559496946	0.302598698	0.183232611	0.357228532	0.295511213
5.63	1.157	5.4888	0.210793	0.03	0.011	0.11	0.645265734	0.390727805	7.01320672	0.645265734	0.390727805	0.74497001	0.616263741
5.63	1.067	5.4534	0.195658	0.03	0.011	0.11	0.566235472	0.342872605	6.92665397	0.566235472	0.342872605	0.657570117	0.54396367
5.63	0.557	4.8158	0.115661	0.03	0.011	0.11	0.208200119	0.126071433	6.345586574	0.208200119	0.126071433	0.24858174	0.205635007
5.63	1.952	7.638	0.255564	0.03	0.011	0.11	1.237792542	0.749520606	7.241980338	1.237792542	0.749520606	1.486069987	1.229326064
5.63	1.593	6.1358	0.259624	0.03	0.011	0.11	1.020814363	0.618133793	7.261027445	1.020814363	0.618133793	1.178265918	0.974700395
5.63	1.446	5.9446	0.243246	0.03	0.011	0.11	0.887224118	0.537240883	7.182598505	0.887224118	0.537240883	1.024712534	0.847675976
5.63	1.364	5.8454	0.233346	0.03	0.011	0.11	0.81404623	0.492929471	7.133029235	0.81404623	0.492929471	0.941117153	0.778523121
5.63	2.27496	7.937	0.286627	0.03	0.011	0.11	1.557231919	0.942950754	7.38176495	1.557231919	0.942950754	1.861930897	1.540250594
5.63	1.81625	7.671	0.236768	0.03	0.011	0.11	1.09452579	0.662768279	7.150360238	1.09452579	0.662768279	1.324490498	1.095662186
5.63	1.63045	7.476	0.218091	0.03	0.011	0.11	0.930181195	0.563252685	7.053104962	0.930181195	0.563252685	1.129271416	0.934170528
5.63	1.37438	7.33	0.187501	0.03	0.011	0.11	0.708940853	0.429285005	6.877666668	0.708940853	0.429285005	0.869975109	0.719672078
5.63	1.3378	7.942	0.168446	0.03	0.011	0.11	0.642490445	0.389047284	6.755915355	0.642490445	0.389047284	0.807509741	0.667998667
5.63	1.93413	8.128	0.237959	0.03	0.011	0.11	1.169467744	0.708147886	7.156340165	1.169467744	0.708147886	1.428745402	1.181905278
5.63	2.09772	8.206	0.255632	0.03	0.011	0.11	1.330432357	0.805616799	7.242302309	1.330432357	0.805616799	1.617195859	1.337797706
5.63	1.84471	8.068	0.228645	0.03	0.011	0.11	1.086102598	0.657667783	7.108877277	1.086102598	0.657667783	1.330163196	1.100354828
5.63	3.04722	8.695	0.350457	0.03	0.011	0.11	2.385033965	1.444209786	7.633312087	2.385033965	1.444209786	2.843015564	2.35183616
5.63	2.89683	8.621	0.33602	0.03	0.011	0.11	2.204623985	1.334966118	7.579982603	2.204623985	1.334966118	2.634439408	2.179295091
5.63	2.58329	8.402	0.307461	0.03	0.011	0.11	1.852968751	1.122028299	7.468597629	1.852968751	1.122028299	2.222806677	1.838778931
5.63	2.41664	8.324	0.290322	0.03	0.011	0.11	1.66839864	1.010265547	7.397539558	1.66839864	1.010265547	2.008935357	1.661857528

Figure A20-1. Observed and modeled rating curves and streamflow from Site 20, West Run Watershed, Morgantown, West Virginia, U.S.A.

Table A20-3. Polynomial rating equations and R^2 values for observed and modeled rating curves at Site 20, West Run Watershed, Morgantown, WV, U.S.A.

	R² Value	Polynomial Equation
Observed Curve	0.98	$y = 9.1928x^2 - 6.1895x + 1.0677$
Manning's Curve (Obs Slope)	0.96	$y = 5.6124x^2 - 3.3138x + 0.6755$
Manning's Curve (Calc Slope)	0.96	$y = 3.3985x^2 - 2.0066x + 0.409$
Chezy's Curve (Obs Slope)	0.96	$y = 5.6124x^2 - 3.3138x + 0.6755$
Chezy's Curve (Calc Slope)	0.96	$y = 3.3985x^2 - 2.0066x + 0.409$
Dingman and Sharma's Curve (Obs Slope)	0.97	$y = 7.0352x^2 - 4.2963x + 0.8733$
Dingman and Sharma's Curve (Calc Slope)	0.97	$y = 5.8198x^2 - 3.5541x + 0.7224$

Table A20-4. Descriptive statistics for observed and modeled streamflow used to generate the rating curves for Site 20, West Run Watershed, Morgantown, WV, U.S.A.

	Sample Size	Mean (m³/s)	St. Dev.	SE of Mean
Observed	44	0.606	0.834	0.126
Manning's Curve (Obs Slope)	44	0.628	0.601	0.091
Manning's Curve (Calc Slope)	44	0.38	0.364	0.055
Chezy's Curve (Obs Slope)	44	0.628	0.601	0.091
Chezy's Curve (Calc Slope)	44	0.38	0.364	0.055
Dingman and Sharma's Curve (Obs Slope)	44	0.744	0.724	0.109
Dingman and Sharma's Curve (Calc Slope)	44	0.616	0.599	0.09

Table A20-5. P-values of the statistical analyses (post-hoc ANOVA) for observed and modeled rating curves at Site 20, West Run Watershed, Morgantown, WV, U.S.A.

	Observed Curve	Rating Equation Curve	Manning's Curve (Obs Slope)	Manning's Curve (Calc Slope)	Chezy's Curve (Obs Slope)	Chezy's Curve (Calc Slope)	Dingman and Sharma's Curve (Obs Slope)	Dingman and Sharma's Curve (Calc Slope)
Observed Curve	-	1	1	0.71	1	0.71	0.97	1
Rating Equation Curve	-	-	1	0.71	1	0.71	0.97	1
Manning's Curve (Obs Slope)	-	-	-	0.60	1	0.60	0.99	1
Manning's Curve (Calc Slope)	-	-	-	-	0.60	1	0.13	0.66
Chezy's Curve (Obs Slope)	-	-	-	-	-	0.60	0.99	1
Chezy's Curve (Calc Slope)	-	-	-	-	-	-	0.13	0.66
Dingman and Sharma's Curve (Obs Slope)	-	-	-	-	-	-	-	0.98
Dingman and Sharma's Curve (Calc Slope)	-	-	-	-	-	-	-	-

Figure A20-2. Box and whisker plots for the results of the statistical analyses (post-hoc ANOVA) of observed and modeled rating curves at Site 20, West Run Watershed, Morgantown, WV, U.S.A.

Figure A20-3. Cross-sectional profile of WRW Site 20, plotting the stream channel's shape, water surface, and bankfull. The profile is created with a Channel Width of 0= Left Bank facing downstream.

Figure A20-5. Photographs showing channel characteristics at Site #20, West Run Watershed, Morgantown, WV, U.S.A. Photo 1 was taken looking upstream in the channel. Photo 2 was taken from the right bank looking downstream.

APPENDIX 21: Site 21

Table A21-1. Streamflow measurements and stage collected at Site 21, West Run Watershed, Morgantown, WV, U.S.A. (Figure 2).

Date	Mean Depth of Cross-Section (m)	Stage(PT in cm)	Barometric Pressure (in cm)	Pressure Corrected Stage (cm)	Stilling Well Offset (cm)	P-Corrected Stage + Offset (cm)	P-Corrected Stage + Offset (m)	SonTec Discharge (m3/s)	Rating Equation Discharge (m3/s)
10/23/2018	0.2374	104.91	86.3	18.61	17.8	36.4	0.3641	0.0911	0.10643814
10/23/2018	0.2402	104.76	86.05	18.71	17.8	36.5	0.3651	0.1104	0.11093318
1/16/2019	0.2003	109.09	87.33	21.76	17.8	39.6	0.3956	0.1909	0.25337654
1/16/2019	0.2070	109.57	87.76	21.81	17.8	39.6	0.3961	0.1790	0.255797903
1/29/2019	0.2198	103.79	76.21	27.58	17.8	45.4	0.4538	0.4779	0.55390459
2/19/2019	0.2015	124.36	100.46	23.9	17.8	41.7	0.417	0.2867	0.359499007
2/19/2019	0.2042	124.45	100.08	24.37	17.8	42.2	0.4217	0.3067	0.383488691
3/19/2019	0.1820	117.39	97.02	20.37	17.8	38.2	0.3817	0.1614	0.187176123
3/19/2019	0.1762	117.33	97.18	20.15	17.8	38.0	0.3795	0.1672	0.176895401
3/20/2019	0.1850	107.92	88.65	19.27	17.8	37.1	0.3707	0.1564	0.13631101
4/2/2019	0.1801	106.1	87.34	18.76	17.8	36.6	0.3656	0.0969	0.113184872
4/3/2019	0.1785	109.63	90.72	18.91	17.8	36.7	0.3671	0.1230	0.119956637
4/15/2019	0.2405	112.32	79.91	32.41	17.8	50.2	0.5021	0.9193	0.831927683
4/15/2019	0.2356	112.21	80.37	31.84	17.8	49.6	0.4964	0.8528	0.797766696
4/23/2019	0.1926	103.81	83.77	20.04	17.8	37.8	0.3784	0.2202	0.171775233
4/25/2019	0.1942	101.71	77.88	23.83	17.8	41.6	0.4163	0.3588	0.355947103
4/26/2019	0.2402	99.75	68.68	31.07	17.8	48.9	0.4887	0.8477	0.752193389
4/30/2019	0.1658	111.53	91.31	20.22	17.8	38.0	0.3802	0.2121	0.180160699
4/30/2019	0.1670	111.38	91.17	20.21	17.8	38.0	0.3801	0.2187	0.179693894
5/14/2019	0.2286	111.64	81.98	29.66	17.8	47.5	0.4746	0.7683	0.670450925
5/15/2019	0.1972	106.65	84.42	22.23	17.8	40.0	0.4003	0.3711	0.276247171
5/22/2020	0.2402	1043.4	1001.45	42	17.8	59.8	0.598	1.2582	1.460874052
10/29/2020	0.3510	1038.6	985.64	53	17.8	70.8	0.708	2.3660	2.308289632

Table A21-2. Modeled streamflow at Site 21, West Run Watershed, Morgantown, WV, U.S.A.

Cross- Section Area (m ²)	A (Cross Section area of flow)	P (Wetted Perimete r)	RH=A/P Hydraulic Radius (m)	Observed Slope (m)	Calculated Slope using ArcGIS (m)	Roughness Coefficient (n)	Manning Discharge (m ³ /s) (Obs Slope)	Manning Discharge (m ³ /s) (Calc Slope)	Chezy Coefficient (C)	Chezy Discharge (m ³ /s) (Obs Slope)	Chezy Discharge (m ³ /s) (Calc Slope)	Dingman & Sharma Discharge (m ³ /s) (Obs. Slope)	Dingman & Sharma Discharge (m ³ /s) (Calc Slope)
11.03	1.317	5.9662	0.220744	0.01	0.029	0.115	0.418292341	0.712326189	6.760053829	0.418292341	0.712326189	0.715922563	0.878393085
11.03	1.318	5.967	0.220882	0.01	0.029	0.115	0.41878439	0.713164118	6.760757963	0.41878439	0.713164118	0.716739392	0.879395284
11.03	1.435	7.5638	0.189719	0.01	0.029	0.115	0.411998186	0.701607629	6.59154878	0.411998186	0.701607629	0.745193013	0.914306133
11.03	1.483	7.5772	0.195719	0.01	0.029	0.115	0.434708612	0.740282091	6.625839217	0.434708612	0.740282091	0.784220659	0.962190662
11.03	1.623	7.8302	0.207274	0.01	0.029	0.115	0.494292995	0.841750639	6.689491462	0.494292995	0.841750639	0.891987233	1.094413639
11.03	1.565	8.1748	0.191442	0.01	0.029	0.115	0.452037681	0.769792433	6.601485807	0.452037681	0.769792433	0.827974486	1.015873923
11.03	1.587	8.1804	0.194	0.01	0.029	0.115	0.462466924	0.787552794	6.616107566	0.462466924	0.787552794	0.846124827	1.03814328
11.03	1.345	7.755	0.173436	0.01	0.029	0.115	0.363734726	0.619417918	6.493700285	0.363734726	0.619417918	0.666322044	0.81753629
11.03	1.301	7.743	0.168023	0.01	0.029	0.115	0.344475348	0.58662038	6.459469211	0.344475348	0.58662038	0.632748658	0.776343804
11.03	1.297	7.38	0.175745	0.01	0.029	0.115	0.353859787	0.602601503	6.508028239	0.353859787	0.602601503	0.641902085	0.787574498
11.03	1.318	7.6754	0.171717	0.01	0.029	0.115	0.354073832	0.602966009	6.482928399	0.354073832	0.602966009	0.648072036	0.795144649
11.03	1.251	7.367	0.169811	0.01	0.029	0.115	0.333582989	0.568071361	6.470878811	0.333582989	0.568071361	0.606884756	0.744610382
11.03	2.162	9.4728	0.228232	0.01	0.029	0.115	0.702116852	1.195661915	6.797747778	0.702116852	1.195661915	1.297697301	1.592195015
11.03	2.155	9.472	0.227513	0.01	0.029	0.115	0.698371473	1.189283764	6.794170227	0.698371473	1.189283764	1.291137918	1.584147055
11.03	1.379	7.548	0.182697	0.01	0.029	0.115	0.386089516	0.657486754	6.550245168	0.386089516	0.657486754	0.700549105	0.859530796
11.03	1.671	8.9992	0.185683	0.01	0.029	0.115	0.472926489	0.805364791	6.567966324	0.472926489	0.805364791	0.88327745	1.083727269
11.03	2.178	9.5484	0.228101	0.01	0.029	0.115	0.707041463	1.204048224	6.797095495	0.707041463	1.204048224	1.308668187	1.60565562
11.03	1.416	8.8638	0.159751	0.01	0.029	0.115	0.362516365	0.617343124	6.405347716	0.362516365	0.617343124	0.684874927	0.840299539
11.03	1.412	8.792	0.160601	0.01	0.029	0.115	0.362772926	0.617780032	6.411013074	0.362772926	0.617780032	0.684055997	0.839294763
11.03	2.072	9.525	0.217533	0.01	0.029	0.115	0.651691048	1.109789864	6.743566131	0.651691048	1.109789864	1.211077215	1.485917481
11.03	1.668	8.8524	0.188423	0.01	0.029	0.115	0.476710682	0.811809039	6.584022845	0.476710682	0.811809039	0.88659794	1.087801307
11.03	2.306	10.0814	0.228738	0.01	0.029	0.115	0.749987054	1.277181931	6.800255583	0.749987054	1.277181931	1.40089664	1.718814276
11.03	3.423	10.456	0.327372	0.01	0.029	0.115	1.413849801	2.407699453	7.218977924	1.413849801	2.407699453	2.569878383	3.153083194

Figure A21-1. Observed and modeled rating curves and streamflow from Site 21, West Run Watershed, Morgantown, West Virginia, U.S.A.

Table A21-3. Polynomial rating equations and R^2 values for observed and modeled rating curves at Site 21, West Run Watershed, Morgantown, WV, U.S.A.

	R² Value	Polynomial Equation
Observed Curve	0.98	$y = 5.563x^2 + 0.4385x - 0.7907$
Manning's Curve (Obs Slope)	0.94	$y = 3.5201x^2 - 0.9027x + 0.2264$
Manning's Curve (Calc Slope)	0.90	$y = 3.4025x^2 + 1.3579x - 0.3888$
Chezy's Curve (Obs Slope)	0.94	$y = 3.5201x^2 - 0.9027x + 0.2264$
Chezy's Curve (Calc Slope)	0.94	$y = 5.9945x^2 - 1.5373x + 0.3855$
Dingman and Sharma's Curve (Obs Slope)	0.95	$y = 5.3559x^2 - 0.4927x + 0.1239$
Dingman and Sharma's Curve (Calc Slope)	0.95	$y = 6.5714x^2 - 0.6046x + 0.152$

Table A21-4. Descriptive statistics for observed and modeled streamflow used to generate the rating curves for Site 21, West Run Watershed, Morgantown, WV, U.S.A.

	Sample Size	Mean (m³/s)	St. Dev.	SE of Mean
Observed	23	0.467	0.524	0.109
Manning's Curve (Obs Slope)	23	0.514	0.237	0.049
Manning's Curve (Calc Slope)	23	0.85	0.433	0.09
Chezy's Curve (Obs Slope)	23	0.514	0.237	0.049
Chezy's Curve (Calc Slope)	23	0.85	0.433	0.09
Dingman and Sharma's Curve (Obs Slope)	23	0.941	0.435	0.091
Dingman and Sharma's Curve (Calc Slope)	23	1.155	0.534	0.111

Table A21-5. P-values of the statistical analyses (post-hoc ANOVA) for observed and modeled rating curves at Site 21, West Run Watershed, Morgantown, WV, U.S.A.

	Observed Curve	Rating Equation Curve	Manning's Curve (Obs Slope)	Manning's Curve (Calc Slope)	Chezy's Curve (Obs Slope)	Chezy's Curve (Calc Slope)	Dingman and Sharma's Curve (Obs Slope)	Dingman and Sharma's Curve (Calc Slope)
Observed Curve	-	1	1	0.03*	1	0.03*	<0.05*	<0.05*
Rating Equation Curve	-	-	1	0.03*	1	0.03*	<0.05*	<0.05*
Manning's Curve (Obs Slope)	-	-	-	0.08	1	0.08	0.02*	<0.05*
Manning's Curve (Calc Slope)	-	-	-	-	0.08	1	1	0.34
Chezy's Curve (Obs Slope)	-	-	-	-	-	0.08	0.02*	<0.05*
Chezy's Curve (Calc Slope)	-	-	-	-	-	-	1	0.35
Dingman and Sharma's Curve (Obs Slope)	-	-	-	-	-	-	-	0.69
Dingman and Sharma's Curve (Calc Slope)	-	-	-	-	-	-	-	-

*= indicates that the difference of the means is significant at the 0.05 level.

Figure A21-2. Box and whisker plots for the results of the statistical analyses (post-hoc ANOVA) of observed and modeled rating curves at Site 21, West Run Watershed, Morgantown, WV, U.S.A.

Figure A21-3. Cross-sectional profile of WRW Site 21, plotting the stream channel's shape, water surface, and bankfull. The profile is created with a Channel Width of 0= Left Bank facing downstream.

Figure A21-4. Plan view profile of WRW Site 21, West Run Watershed, Morgantown, WV, U.S.A. (Figure 2). Showing the positioning of stilling well in relation to where the streamflow was measured. Along with the channel width at the stilling well, point where cross-sections were performed, and 6.0m upstream and downstream from the stilling well.

Figure A21-5. Photographs showing channel characteristics at Site #21, West Run Watershed, Morgantown, WV, U.S.A. Photo 1 was taken looking upstream in the channel. Photo 2 was taken from the right bank looking downstream.