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Dry river watershed valuation and management plan

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Dry River Watershed Valuation and Management Plan

An Honors College Project Presented to

the Faculty of the Undergraduate

College of Integrated Science and Engineering

James Madison University

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by Julia Lynn Hutchens

Accepted by the faculty of the Department of Engineering, James Madison University, in partial fulfillment of the requirements for the Honors College.

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PUBLIC PRESENTATION

This work is accepted for presentation, in part or in full, at the Honors Symposium on 4/5/19.

Dry River Watershed Valuation and Management Plan

Honors Track 3 Thesis

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Executive Summary

Water quality has become a major environmental and human welfare concern in the world today, it's no longer just for developing countries. There have been many incidences in the US of health problems related to water quality and a shortage of water. The City of Harrisonburg and the surrounding community also have a need for a well-developed watershed management plan. The focus of this study will be the Dry River because that is a main source of the city's water. The Dry River watershed is threatened by illegal dumping, erosion from primitive roads and future road building sedimentation, a lack of awareness about the resource, and the potential for hydraulic fracturing for natural gas. These threats suggest that the full value of the Dry River watershed is not fully understood by the community and accounted for in the public use plans of the City and US Forest Service.

Problem Statement: The goal of the research is to measure and assess the true value of the environmental services provided by the Dry River watershed, including both the land owned by the City of Harrisonburg and the George Washington National Forest (GWNF), which may assist in future management decisions.

The research includes background of the area of focus, a literature summary on ecosystem services, a description of the methods used, outcomes, and recommendations for future work.

Background

The Harrisonburg Environmental Performance Standards Advisor Committee (EPSAC) has identified a need to create an updated management plan for the Dry River Watershed to increase protection and preservation of the water supply for Harrisonburg, Rockingham Country and the surrounding region. The headwaters of the Dry River supply approximately half of the community's water supply. They are located on Shenandoah Mountain within George Washington National Forest while additional land along the banks of the Dry River is owned by the city. The current GWNF management plan has had success in preserving the water supply region. However, in the past, both GWNF land and city land surrounding the water supply have been degraded through illegal dumping, damaging motor vehicle off-road use and other activities.

Figure 1: Illegal road in Drive River Basin.

The City of Harrisonburg and Rockingham County are in the Potomac-Shenandoah River Basin. This river basin provides water supply to 4 states and the District of Columbia. Based on the Virginia Employment Commission's population estimates, population in this area will increase about 41.5% in between 2000 and 2040. The estimated increase in water demand, required by the WSP Regulation, for this river basin is 32.6% within the timeframe of 2010 and 2040. A water supply plan was for made for each region of the basin. For Rockingham and Augusta County, water demand was expected to increase 3% in the planning period, while population is expected to increase in the towns and cities much more. An estimated year of deficiency was made for each county and city. Rockingham County is expected to have the first deficiency in the area in the year 2020 of an estimated 1.27 MGD[1].

Figure 2: Area of interest in the Dry River Watershed, located to the west of Harrisonburg, VA courtesy of Google Maps.

The Dry River watershed provides many opportunities for public recreation, including picnicking, hiking, fishing and hunting. In fact, biologists from VA DGIF and the US Forest Service have stated that the Dry River is one of the most densely populated native brook trout streams in the Mid-Atlantic region. Today, more than 830,000 anglers travel to Virginia's waterways each year, spending more than $1.1 billion on fishing-related activities. More than 20% of the anglers are nonresidents, boosting the economy with out-of-state dollars[2]. Changing climate can affect many of these recreational opportunities, especially trout fishing. Brook trout habitat requires the water temperature to be less than 23°C. With increasing air and groundwater temperatures, the water temperature may increase in certain parts of the river to the point where it would be unsuitable for brook trout. However, compared to many other rivers in the area, the Dry River will still have large sections with temperatures suitable for brook trout habitat, making it one of the last best places for southern, native brook trout fishing[3].

One of the threats facing the water source is the Marcellus Shale in the GWNF that has caused many natural gas developers to show interest in the area, specifically for hydraulic fracturing. The federal government owns 100% mineral rights of about 84% of the GWNF and the other 16% is owned privately. If the permission were to be granted for fracking, it would have a negative impact on the soil, air, and water quality. One of the greatest impacts will be from water withdrawals. It is estimated that 26,300,000 gallons of water will be used for drilling and 1,273,000,000 will be used for fracturing. Removing this large amount of water from the Dry River could lead to changes in water quality, insufficient stream flow to maintain stream habitat, and decrease the resource needed for Harrisonburg's drinking water[4].

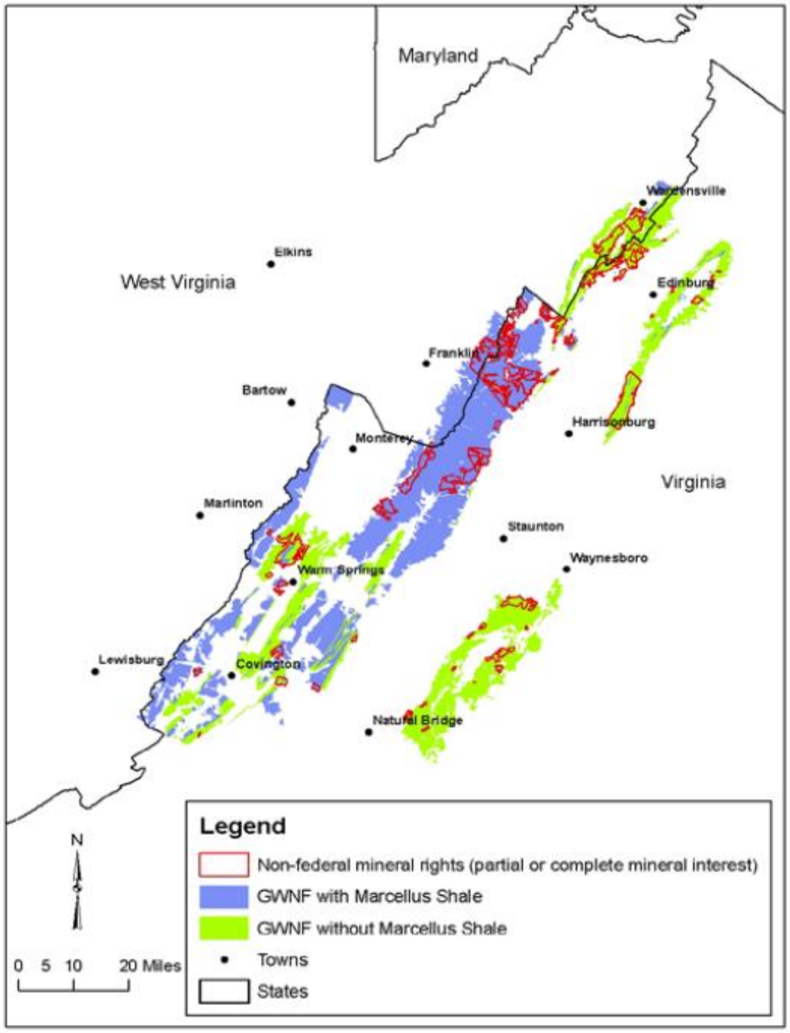

Figure 3: Non-federal mineral rights on GWNF. Interpreted surface and subsurface extent of the Marcellus Shale on GWNF in Virginia and West Virginia using U.S. Geological Survey geologic map data[4].

Literature Review

In 2010, the United Nations recognized the right to water as a fundamental human right and established that everyone has the right to physical and economical access to enough safe drinking water[5]. Water scarcity is a real threat to many people around the world including developed countries such as the United States. The City of Harrisonburg plays an important role to prevent this from happening to its citizens and the citizens of the surrounding area. For Harrisonburg to do this, they need to create an effective plan for managing its water resources, specifically the Dry River – its main source of water. The Dry River watershed is threatened by illegal dumping, erosion from primitive roads and off-road use, a lack of awareness of the true value of the resource, and the potential for hydraulic fracturing for natural gas. To improve the city's management plan for the Dry River the full value of the environmental services must be measured and recognized. Ecosystem services evaluation has been used in many areas around the world and "are becoming a major driving force in resource management, conservation, and policy and decision making"[6].

Ecosystem services are defined as "the conditions and processes through which natural ecosystems, and the species that make them up, sustain and fulfill human life"[7]. Examples of ecosystem services would include timber, food, climate regulation, waste treatment, and erosion control for forests or water supply, waste treatment, recreation activities, and pollution control for rivers[7]. The concept of valuing these ecosystem services started in early 1990s to bridge economics, conservation, development, and policy[6]. Ecosystem values can be related to material outputs of the ecosystem, regulating services, ecological needs, or recreational uses but they are typically non-use value instead of consumptive value. Because these do not directly benefit one consumer, these ecosystems face the tragedy of the commons[7]. An example of this is the decline in the health of the Chesapeake Bay because the first settlers only saw the value in what they could directly consume leading to continuous under-valuation of the ecosystem and the services it provides[7]. Putting a dollar value on ecosystems could be seen as disrespectful to those who consider them as priceless, but it helps prevent situations similar to the Chesapeake Bay by making the value more explicit and consistent[7].

There are many benefits to ecosystem services and acknowledgement of their full value, however there are a few negative effects that come with it as well. Ecosystem service valuation is now acknowledged for its positive role in sustainable development in all areas – economic, environmental, and social well-being[6]. Part of this includes the fact that ecosystem services are being recognized for lasting longer then human development[7]. It can be used to not only look ahead to the future but to look back on the past to estimate value lost from resource degradation, as opposed to current value, which can inform decisions about resource restoration and management[8]. Increasing value in one area can help to increase value in others. Specifically, for this project, the increased economic value of streams for recreation sport fishing would also increase additional benefits such as improved water quality for other wildlife and human consumption[8]. Valuation is especially useful if the benefits can be measurably related to riparian landscape and habitat conditions that drive fishing quality, such as fish biomass[9]. Overall it benefits local economies, strengthens communities, increases environmental stewardship, outdoor participation, and preserves tradition[10]. A negative effect associated with this project would be higher angler use leading to damaged riparian buffers, increased erosion, increased littering, and higher sedimentation[10].

A lot of ecosystem service valuation approaches have been developed but most are designed to address specific policy questions and are generalized to larger-scale environments.

Understanding local ecosystem services is limited by the complexity of local environments and the lack of data. Local scale valuation for policy and decision support requires a combination of approaches and availability of data and knowledge for that area. It also must be driven by local need and understanding of the incentives that individual decision-makers face in managing ecosystems in different ways[6]. Without local data and knowledge, using global averages will most likely lead to underestimation of the true value of an area[7]. There are numerous approaches to estimate economic value of an area based on the ecosystem services it provides. One method is the Total Economic Value (TEV) method. It is a monetary valuation method that views economic goods and services as the flow of benefits from nature to humans and is broken down into use (consumption) and non-use (intangible human benefits)[6]. The Economics of Ecosystems and Biodiversity (TEEB), is another method, created by ecologist and economist. It argues that ecosystem service valuation must start with understanding biophysical generation of services and acknowledges that services can benefit people in multiple and indirect ways[6]. Another method is the Millennium Ecosystem Assessment (MA), which is the first international framework for ecosystem service valuation. It requires understanding current state of ecosystem services and the trends in production, flow, pressures, and threats[6]. The Multi-Criteria Decision Analysis (MCDA) is more comprehensive than cost-benefit analysis. It includes "economic efficiency, equity within and between generations, environmental quality, and various interpretations of sustainability." Including sustainability makes the biggest difference because it emphasizes the ecosystem as a whole rather than individual components[7]. One of the most common methods is willingness-to-pay, which takes "all of the individuals and their respective values aggregates them, counting each one with the same weight." One major flaw with this method is that it is inherently subjective[7]. The Contingent Valuation Method (CVM) is related to willingness-to-pay in that it uses a stated preference framework by asking respondents about their willingness-to-pay or willingness-to-accept. This method relies on the stated intentions of individuals' willingness to pay for recreation resources or activities, contingent on hypothetical changes in the quantity or quality of the environmental amenity. Potential errors when using this method includes not understanding the hypothetical question, biases, and treating the survey too casually[11]. The method used in *Economic Value of Stream Degradation across the Central Appalachians* starts with classifying ecological conditions and quantifying the current provisions of nature-based recreational opportunity. It then projects potential provisions of the ecosystem service across the region by fitting predictive habitat model to the ecological sampling data. Lastly, it estimates realized and lost value with regional probability based on recreational expenditure data[8]. These methods can be applied to many different scenarios but to get the best value it is better to use multiple different methods.

The purpose in determining ecosystem services valuation is to help individuals, organizations, policy makers and government agencies make decisions about resource use. It is something the VDGIF uses to "provide opportunity for all to enjoy … outdoor recreation"[10]. It is what makes it possible to the EPA to finalize the Clean Water Rule, which makes more clear protection of headwater streams that are important for fishing, drinking, and local and national economy[2]. An organization that assists with this on both a regional and international scale is the Intergovernmental Platform on Biodiversity and Ecosystem Services (IPBES), which focuses on the roles that institutions, government, and decision-makers play toward ecosystem services valuation[6]. The types of decisions that ecosystem service valuation can help make usually revolve around the improving the ability of a resource to be used or protected. For example, with a trout stream, valuation can help decided when and where fish are stocked, how access can be increased, and how signage can assist anglers in identifying opportunities and use the resource wisely[12]. It can help identify threats to a service, such as residential and commercial developments, road construction, improper agricultural practices, and invasive species to trout habitat. Approaches to mitigate those threats, such as stabilizing banks, increasing fish passage, and restoring riparian areas, can be developed from there[12].

There are many methods of valuing ecosystem services that have different focuses. Having many methods help to give the best estimated value for any situation. The main method used for valuing the recreational ecosystem services for the Dry River in Harrisonburg, VA will be willingness-to-pay along with some estimation similar to what was used in the Central Appalachians study[8]. This economic value will help the city policy makers do a cost-benefit analysis, but they still need to acknowledge the moral reasons for protecting the environmental, not just the economical ones[7].

Methods

The ecosystem services that were measured and evaluated were the recreational experiences, direct water supply, energy savings, carbon sequestration, and energy offset. Most of the value calculations were done using data from the city, GWNF or standards set by the EPA. One key set of data that the city did not have was the recreational use of the area. To collect data for the number of users and the types of activities they participated in, game cameras were placed throughout the watershed to track this information. Some anticipated activities include fishing, camping, swimming, dumping trash, and hunting.

The number and location of cameras varied throughout the year based on the season and anticipated heavily used areas, with six cameras total from Riven Rock Park to Switzer Lake. Every 3-4 weeks the memory cards and batteries would be switched out. After collecting the used memory cards, the pictures would be manually analyzed, and the data would be recorded in an Excel spreadsheet according to the type of activity and age of user. Statistics such as average number of users for an activity at each location and total users were calculated. The total number of users, referred to as person activity days, would then be combined with previously determined willingness-to-pay data to calculate the value each activity is worth to the users[13]. Each value would be weighted to account for counting error. Tables showing raw data and data analysis are shown below.

Table 1: Sample of Raw Dry River Usage Data

Dry River Usage Data											
Date	Number of Days	Location	Fishing	Boating	Biking	Day Use -	AGES:	Under Elementary	Elementary and Middle	High School and College	Adult
5/19-5/24	6	1	6		2	246		6	35	42	121
5/19-5/24	6	2	3		1	98		2	7	18	27
		3									
5/19-5/24	6	4	3			24		1		1	20
		5									
		Total	12	0	3	368		9	42	61	168
Date	Number of Days	Location	Fishing	Boating	Biking	Day Use -	AGES:	Under Elementary	Elementary and Middle	High School and College	Adult
5/24-5/31	8	1	11	3		251		13	48	44	146
5/25-6/6	13	2	13			256		13	36	41	166
		3									
5/25-6/10	17	4	12			38					38
5/25-6/10	17	5		75		204		1	13	5	185
		Total	36	78	0	749		27	97	90	535

Table 2: Data Analysis of Dry River Usage Day

TOTALS FOR EACH LOCATION											
Date	Number of Days	Location	Fishing	Boating	Biking	Day Use -	AGES:	Under Elementary	Elementary and Middle	High School and College	Adult
5/19-2/5	136	1	147	7	15	2288		83	441	182	1054
5/19-9/11	104	2	39	0	8	1615		59	215	115	768
6/13-9/8	89	3	15	0	3	451		2	46	43	266
5/19-10/22	123	4	113	0	2	211		2	2	2	155
5/25-1/5	202	5	28	643	10	2658		2	81	12	675
10/7-10/20	14	6	16	0	0	6		0	0	3	19
		Total	358	650	38	7229	8275	148	785	357	2937

AVERAGE PEOPLE PER DAY											
Date	Number of Days	Location	Fishing	Boating	Biking	Day Use -	AGES:	Under Elementary	Elementary and Middle	High School and College	Adult
5/19-2/5	136	1	1.08	0.05	0.11	16.82		0.61	3.24	1.34	7.75
5/19-9/11	104	2	0.38	0.00	0.08	15.53		0.57	2.07	1.11	7.38
6/13-9/8	89	3	0.17	0.00	0.03	5.07		0.02	0.52	0.48	2.99
5/19-10/22	123	4	0.92	0.00	0.02	1.72		0.02	0.02	0.02	1.26
5/25-1/5	202	5	0.14	3.18	0.05	13.16		0.01	0.40	0.06	3.34
10/7-10/20	14	6	1.14	0.00	0.00	0.43		0.00	0.00	0.21	1.36
	Overall People Per Day		1.77	3.22	0.19	35.79		0.73	3.89	1.77	14.54

These methods were developed from other studies that used trail cameras for data collection. A study performed by the University of Munich in Bavaria used cameras to track the number of joggers, walkers, and dog walkers. They also did evaluation through manual counting and recorded gender and equipment in an Excel file. "Trigger trail cameras provide in depth and very detailed information about outdoor recreation activities and allow assessing various monitoring and evaluation questions[14]." More common uses of game cameras for collecting data are related to wildlife. Ohio State notes them being use for observation of wildlife, identification of problem animals, assessing habitat management plans, locating game, estimating population numbers, and understanding animal activity patterns[15]. At Texas A&M, they are used to "identify areas of high priority and monitor wildlife in these specified areas." The cameras were placed in a way to cover as much area as possible, 1 camera per 160 acres, rather than at specific locations[16].

Determining how much value the Dry River provides as a water source, it must be compared with the other water resource options in the area. The chart below shows all of the options Harrisonburg and the surrounding communities have for water and compares them based on water quality, energy efficiency, treatment required, and future flow requirements[17].

Table 3: Comparison of Harrisonburg, VA's different water sources

	Water Quality	Energy Efficiency	Treatment Requirements	Future Flow Requirements
Dry River	pristine and soft	0 kWHrs/MG 0 kW	Filtration, Buffer	~ 65.2% or 13.5 MGD
North River	moderate algae, turbidity and moderately hard	2,150 KWHrs/MG 530 kW	Alum Coagulation, Precipitation, Filtration, Buffer	99.8% or 5.5 MGD
Shenandoah River	high turbidity, algae and moderately hard	3,108 kWHrs/MG 708kW	Alum Coagulation, Precipitation, Filtration, Buffer	99.6% or 12.2 MGD
Silver Lake	algae, hard	1,805 kWHrs/MG 137 kW	Alum Coagulation, Precipitation, Filtration, Buffer	Unreliable long-term option

For valuing the direct water supply of the Dry River, 2019 water rates for the city and rural area were multiplied by the average use of each and converted to a per year basis. This does not factor in savings on treatment due to water quality. The value of energy savings, due to the energy efficiency, was calculated using the commercial cost of electricity and amount of water extracted per day.

Carbon dioxide sequestration is an important service to humans that can go overlooked that forests can make a significant impact on. Standards from the EPA for typical sequestration rates of a US forest and the social cost of carbon were used to determine the value of sequestration for this area of the watershed. The carbon dioxide offset due to the energy savings can also be calculated by using the amount of energy that it is saving in CO_2 equivalents, from EPA methodology, and the social cost of carbon[18].

Outcomes

The most popular activities participated in, at the locations of the cameras, were biking, boating, fishing, and picnicking, or day use. Some occurrences of illegal activities, such as off-roading and camping in prohibited locations, were observed and noted. The site that saw the most use was the downstream picnic shelter at Riven Rock Park with the recorded total number of users at 2,288, averaging at 17 people per day. The total number of people recorded in the area is 8,275 and it is assumed that an underestimation due to error in the cameras and manual counting. For each activity the Region 8 Average Economic Value (willingness-to-pay), person activity days (number of users), and estimated counting efficiency (accounting for error) are multiplied together to get the value of each, along with the total weighted average.

Table 4: Calculations and value for most popular activities in the Dry River Watershed

Activity	Region 8 Average Economic Value ($2016)	Person Activity Days	Estimated Counting Efficiency	Projected Value in 2016 Dollars
Biking	86.20	38	0.90	$ 3,639.56
Boating (Non-motorized)	108.38	650	0.90	$ 78,274.44
Fishing	70.98	358	0.70	$ 36,301.20
Picnicking	49.17	7229	0.80	$ 444,312.41
Total		8275		**$ 562,527.61**
Weighted Average	66.70	8275	0.80	**$ 689,928.13**

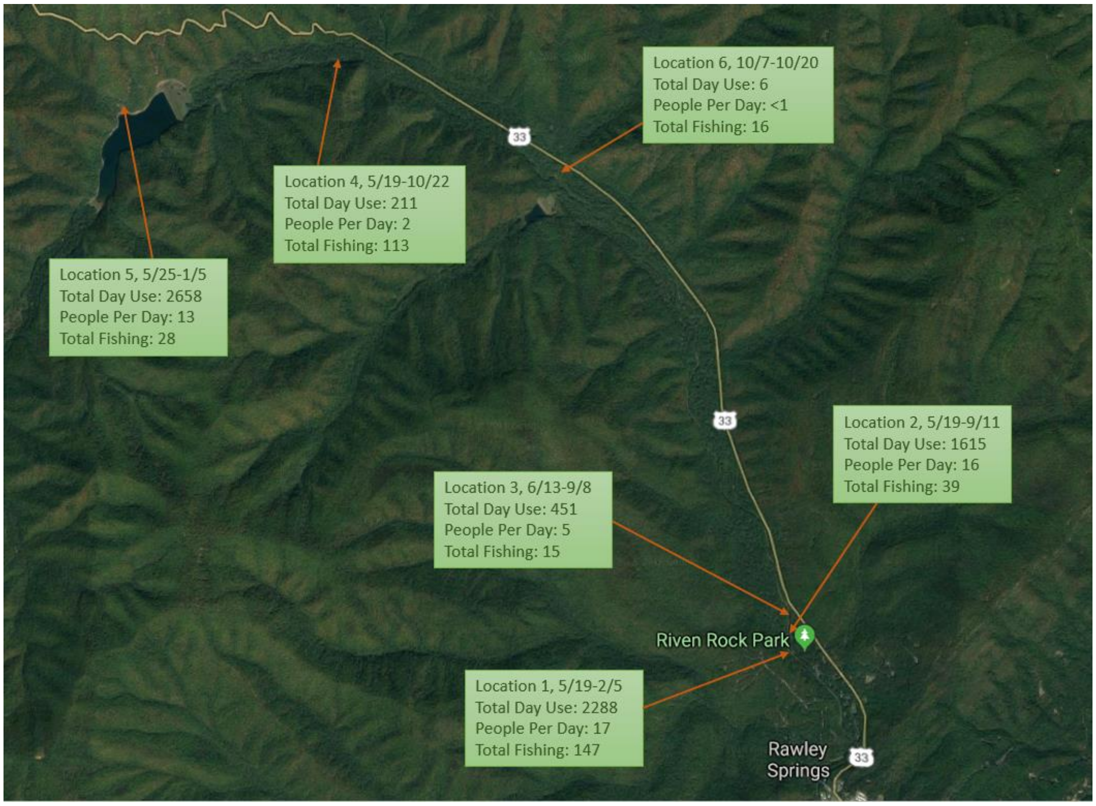

Figure 4: Graphic showing the location of each camera and highlighting site-specific data.

The direct water supply was calculated using the 2019 City water rate of $3.21/1000 gal and average use of .5 MGD. The rural water rate is $5.31/1000 gal and average use is 3.5 MGD.

$$\frac{\$3.21}{1000\ gal} \times \frac{500{,}000\ gal}{day} \times \frac{365\ days}{year} = \$585{,}825/year$$

$$\frac{\$5.37}{1000\ gal} \times \frac{3{,}500{,}000\ gal}{day} \times \frac{365\ days}{year} = \$6{,}860{,}175/year$$

$$Total = \$585{,}825/year + \$6{,}860{,}175/year = \$\mathbf{7,446,000/year}$$

The city of Harrisonburg estimates that 3,838,340 kWHrs of energy are saved per year by using the Dry River as a water source[17]. This along with the cost of electricity at $0.087/kWHr was used to find the energy savings value.

$$\frac{\$0.087}{kWHrs} \times \frac{3{,}838{,}340\ kWHrs}{year} = \$\mathbf{333,936/\boldsymbol{year}}$$

To value carbon sequestration, 1.22 metric tons CO_2/acre*year is the sequestration rate used, the social cost of carbon is $40.45/metric ton, and the area of the watershed is 1,288 acres[18].

$$1{,}288\ acres \times \frac{1.22\ metric\ tons\ CO_2}{acre \cdot year} \times \frac{\$40.45}{metric\ tons\ CO_2} = \$\mathbf{63,560/\boldsymbol{year}}$$

The carbon dioxide offset from energy savings used EPA methodology to convert 3,838,340 kWHrs/year saved to 2857 metric tons CO_2/year with the social cost of carbon to determine the value[18].

$$\frac{1{,}559\ lbs\ CO_2}{MWhr} \times \frac{0.0004536\ metric\ tons}{lbs} \times \frac{0.0001\ MWHr}{kWHr} \times \frac{3{,}838{,}340\ kWHrs}{year} \times \frac{\$40.45}{metric\ tons\ CO_2} = \$\mathbf{109,795/\boldsymbol{year}}$$

The total value of the area is the sum of the estimated values, which is **$8.52-8.64 million**. This value shows the city and other organizations that can influence management decisions how important this area is to care for. The value of each ecosystem service shows more specifically where the value of the watershed comes from, therefore assisting in any trade-off or cost-benefit analysis.

Timeline

April 2018

- Honors Capstone Project Proposal, 11 hrs
- Reviewing material for literature review, 4 hrs

May 2018

- Dry River visit with Dr. Striebig, 2 hrs
- Trail camera usage research, 2 hrs
- Put up trail cameras, 5 hrs
    - 2 at Riven Rock Park (Locations 1&2)
    - Skidmore Fork (Location 4)
    - Switzer Lake (Location 5)

June 2018

- Trail cameras, 1hr
    - Camera at Skidmore Fork moved to river crossing
    - Camera added closer to the city intake dam (Location 3)
- Data collection and analyzation, 10 hrs

July 2018

- Data collection and analyzation, 7 hrs

August 2018

- Data collection and analyzation, 10 hrs
- Beginning of school year meeting with Morton and Striebig, 1 hr
- Literature review, 3 hrs

September 2018

- Literature review, 7 hrs
- Creating willingness-to-pay survey, 2 hrs
- Trail cameras
    - All cameras brought in because of weather
    - Camera at dam either lost or stolen
- Data collection and analyzation, 6 hrs
    - Created graphic, 1 hr

October 2018

- Literature review, 5 hrs
- Trail cameras put back out, 4 hrs
    - Dry Run Road (Location 6)
    - Skidmore Fork
    - Switzer Lake
    - Ordered 3 new cameras, memory cards, and batteries
- Creating willingness-to-pay survey, 1 hr
- Data collection and analyzation, 5 hrs

November 2018

- Literature Review, 2 hrs
- Trail cameras, 1 hr
    - New supplies received
- Presenting at the Pure Water Forum, 7 hrs

December 2018

- Trail cameras, 3 hrs
    - Camera up at Riven Rock, Location 1
    - Other locations have heavy hunter use
- Literature review, 11 hrs

January 2019

- Data collection and analyzation, 1 hr
- Thesis, 3 hrs

February 2019

- Trail Cameras, 7 hrs
    - Cameras collected for inventory
    - Camera return to Locations 1 & 3
- Thesis, 3 hrs
- Presentations, 2 hrs

March 2019

- Data collection and analyzation, 3 hrs
- Thesis, 10 hrs
- Presentations, 15 hrs
    - MAURC

April 2019

- Data collection and analyzation, 2 hrs
- Presentations, 1
    - Honors Symposium
    - xChange
- Thesis, 3 hrs

Future Work

The current established value of the Dry River Watershed is from a limited number of ecosystem services. This value is of use to the city and other organizations as they are making decisions that affect the area, however further valuation of services would only assist more and bring more awareness. More services that could be valued would include habitat for key species, such as salamanders and brook trout, flood mitigation, erosion prevention, and savings from lack of water treatment needed. Additional work could also be determining local willingness-to-pay data through surveying. A survey and plan were already created but not able to be carried out and is attached. This was influenced from the South River Angler Survey conducted by Brad Fink[19].

Purpose: identify number of anglers that used the Dry River and why they fish there

Survey's done by Dr. Striebig, Mossy Creek employees and other volunteers

1. Date, Time, Location along Dry River
2. Age? Young Adult Middle-Aged Elderly
3. Gender? Male Female
4. Where are you from? City/town, state
5. How long have you been fishing today (hours)?
6. How much longer do you plan on fishing today (hours)?
7. Fishing from: bank, wading, kayak, canoe?
8. Fishing with a guide? Yes No
9. How much money do you think you spent today on fishing? Including gas, food, drink, bait, lodging

10. How much would you be willing to pay to fish along the Dry River? Note, there are no plans to make people pay.
11. How much would you be willing to pay/donate per year to maintain access to all activities (hiking, picnicking, fishing, hunting) along the Dry River?
12. How often do you fish?

    Once per week Multiple times per week 1-3 times per month A few times per year
13. How often do you fish in the Dry River?

    Once per week Multiple times per week 1-3 times per month A few times per year
14. In general, how satisfied are you with fishing in the Dry River?

    1 (not very) 2 3 4 5 (extremely)
15. What type of fish are you hoping to catch?
16. What type of fish are you catching?
17. How many have you caught today?
18. Do you usually keep your fish or catch and release?
19. Are you: spin fishing, fly fishing, or both?
20. Why do you like to fish on the Dry River? (Quality of Fish, Scenery, Close to Home, etc.)
21. What do you not like about fishing on the Dry River? (Quality of Fish, too crowded, pollution, etc.)

Resources

1. Virginia Department of Environmental Quality. Commonwealth of Virginia State Water Resources Plan. 2015. 488 pages.
2. Dunlap, K. and Taylor, M. Virginia's Water Resources. 2016. Trout Unlimited. 4 pages.
3. Hitt, N. New inference from citizen science for trout habitat assessment and climate change research. 2018. US Geological Survey, Leetown Science Center. 48 pages.
4. George Washington National Forest. Chapter 3: Affected Environment and Environmental Consequences. Section D: Federal Oil and Gas Leasing Availability. 85 pages.
5. United Nations. General Comment No. 15. The right to water. November 2002. UN Committee on Economic, Social and Cultural Rights.
6. Pandeya, B., Buytaert, W., Zulkafli, Z., Karpouzoglou, T., Mao, F., and Hannah, D.M. Comparative analysis of ecosystem services valuation approaches for application at the local scale and in data scarce regions. 2016. Ecosystem Services, Elsevier. 10 pages.
7. Holtan, R. The Economic Value of the Ecosystem Services of the Chesapeake Bay. 2005. MS. Thesis. Department of Environmental Sciences, University of Virginia. 39 pages.
8. Jackson, L., Rashleigh, B., and McDonald, M. Economic Value of Stream Degradation across the Central Appalachians. 2012. The Journal of Regional Analysis and Policy. 10 pages.
9. Melstrom, R.T., Lupi, F., Esselman, P.C., and Stevenson, R.J. Valuing recreational fishing quality at rivers and streams. 2015. Water Resources Research, American Geophysical Union. 11 pages.
10. Virginia Department of Game and Inland Fisheries. Virginia Stocked Trout Management Plan. 2016. 78 pages.
11. Schuett, M., Pierskalla, C., and Oh, J. Estimating the Recreational Value of Anglers' Visitation to Pay Fishing Ponds or Lakes in West Virginia: Summary Report. 2010. Journal of Park and Recreation Administration. 26 pages.
12. North Carolina Wildlife Resource Commission. North Carolina Trout Resources Management Plan. 2013. 16 pages.
13. Rosenberger, R.S., E. M. White, J. D. Kline, and C. Cvitanovich. Recreation Economic Values for Estimating Outdoor Recreation Economic Benefits From the National Forest System. 2017. USDA. General Technical Report PNW-GTR-957
14. Lupp, G. et. al. Using trigger trail cameras for visitor monitoring – Application in Bavaria. 2016. University of Munich. 3 pages.
15. Brown, J. and Gehrt, S. The Basics of Using Remote Cameras to Monitor Wildlife. 2009. The Ohio State University. 8 pages.
16. Dreibelbis, J., Locke, S., Cathey, J., and Collier, B. Potential Uses for Trail Cameras in Wildlife Management. 2009. Texas A&M. 16 pages.
17. Harrisonburg Public Utilities. Raw Water Supply Management Plan. 2016. The City of Harrisonburg. 52 pages.
18. EPA AVERT. US national weighted average CO2 marginal emission rate, year 2017 data. 2018. US Environmental Protection Agency.
19. Fink, B. Angler Survey on the South River and South Fork Shenandoah River. 2017. Virginia Department of Game and Inland Fisheries.