Watershed Environmental Analysis: Waterflow Function and Vulnerabilities

Abstract

The environmental impacts on the proposed area for the sPower solar panels has been a primary concern from the citizens of Spotsylvania County during the special use permit process. This project will discuss the function of watersheds, specifically within the sPower Spotsylvania County solar panel farm sites, to effectively present the findings from sPower's permitting process and the concerned citizens of Spotsylvania to answer the following questions: *How do the sPower solar farm watersheds function, what are their vulnerabilities, and how is sPower addressing them*? The information presented is a collection and analysis of data using ArcGIS software and written documents to promote the construction of the proposed solar farm in Spotsylvania County. I will be examining the effects that the project will have on the watersheds and groundwater within the proposed sites through a watershed integrity and sustainability lens. This framework will allow me to define the major components of a watershed, why it is important to maintain, and how to additionally identify the vulnerabilities within a watershed. Specifically, this paper will discuss the hydrology of the watersheds of the proposed sites, including the potential impacts on Fawn Lake.

Introduction

In 2010, the University of Richmond released their Climate Action Plan, which outlines the the steps necessary for the University to become carbon neutral by 2050 (Andrejewski, 2019). After switching from coal to natural gas on campus in 2011, purchasing renewable energy credits in 2013, and installing an onsite solar array in 2016, there was still a large amount of greenhouse gas (GHG) emissions that needed to be cut in order to reach a benchmark target of 30% total GHG reduction in 2020. In 2018, University of Richmond (UR) announced their agreement to commit 100% of the campus' electricity demand to be matched by renewable energy. UR invested in 20 megawatts (Andrejewski, 2019) of energy with the purchase of offsite solar in Spotsylvania County, Virginia in order to reach this goal. The investment is going towards a solar project installed and proposed by the solar company Sustainable Power, also known as sPower. The 500-MW solar project has recently been approved by the Spotsylvania County Board of Supervisors (Kenning, 2019).

Despite the many benefits of producing clean energy through solar, the approval of the project has faced great opposition from local citizens. The community is highly concerned with the impacts that the project will have on their county. Although the project is not going through a formal Environmental Impact Assessment (EIA) process, like the process which occurs with the National Environmental Policy Act (NEPA), proper steps have been taken through Spotsylvania County and the Special Use Permit (SUP) process. Even with the thorough environmental analysis that was conducted to acquire the SUPs, the project continued to receive resistance from Spotsylvania residents. One of the major environmental concerns is how the site will affect the neighboring Fawn Lake and its community. Additionally, runoff, erosion, sediments, the protection of endangered species, hazardous materials and chemicals are also primary concerns within the surrounding watershed. This paper will address these primary concerns of the citizens, by focusing on the general function, flow, and vulnerabilities of the watershed and what is being done to protect its integrity.

Background

What is a watershed?

Defining the term watershed and watershed integrity, along with all of its related components, will assist in the understanding and the discussion of this topic when observing the potential environmental impact of the watersheds within the sPower solar farm sites. A watershed is the landscape that provides surface water to a single location, such as a point on a stream of river, a single wetland, a lake or another waterbody (Flotemersch, 2015). Watersheds are often subdivided into five different basic units based on the size of the watershed (from smallest to largest): catchment, sub-watershed, watershed, sub-basin and basin (Freie

Universität, 2007). It consists of physical, chemical, and biological elements that are intertwined by the flow of the water. They are also defined by their topographic high and low points, representing areas that collect precipitation and distribute water to a specific location (Edwards, 2015). Streams and rivers are defined by the low points on the land where surface flow accumulates due to the topographical features of the watershed (*Figure 1*).

Groundwater and Aquifers

Groundwater and groundwater aquifers are other important elements of a watershed which reside underneath the surface of the land (*Figure 2*). The term groundwater refers to all the underground areas where the bedrock beneath the soil surface is saturated. While the rock, or the soil material that holds the water is called an aquifer (Edwards, 2015). Wells can be drilled into aquifers in order to extract water for consumption. Precipitation eventually adds water, or recharge, into the porous rocks of the aquifer (USGS Water Science School, 2018). In many cases, the surficial boundaries of the watershed are overlaid on aquifer boundaries; however, the two do not always align perfectly. This interdependent system explains why the watershed is not only affected by precipitation and surface water, as it is also significantly impacted by groundwater levels (Flotemersch, 2015).

The boundary lines can be differentiated by taking into account what distinguishes ephemeral from perennial and intermittent streams: ephemeral streams are affected directly by precipitation, while perennial and intermittent streams receive groundwater inputs for a portion or all of the year (Flotemersch, 2015). However, since groundwater occurs within watersheds and are approximately beneath surface water divides, watersheds are primarily used as the basic hydraulic unit for both surface water and groundwater planning purposes. Understanding the alignment of surface and groundwater, their interaction, and assessing human influence are a major challenges but are important in defining a watershed.

Watershed Ecosystem Services

Additionally, watersheds provide a wide variety of ecosystem services that are valued by humans. Many of the services that a watershed provide are directly related to the flow and function of the water and its elements (Flotemersch, 2015). These include supporting services (e.g. soil and sediment control), provisioning goods and services (e.g. water storage and food), regulating services (e.g. climate regulation, flood regulation and water purification) and cultural services, such as recreation and spiritual activities (U.S. EPA, 2018). However, in many regions water is viewed as an exploitable commodity for human use (Flotemersch, 2015). As a result, the wider range of watershed services have garnered limited recognition outside of the science field. The quality and amount of services that are produced by watersheds are exponentially declining because of the accelerated rate of land-use change, water consumption, and further, climate change (Flotemersch, 2015). Governments have recognized the stress that humans place on natural resources within watershed and have steadily implemented policies and provisions, such as EIAs and SUPs, to increase the sustainability and maintain the integrity of water-dependent services (Flotemersch, 2015).

Watershed Integrity

In an environmental context, integrity can be defined as the capacity of a system to support and maintain the full range of ecosystem processes, functions, and services essential to the long-term sustainability of its natural resources (Flotemersch, 2015). In order to assess watershed integrity as the two definitions combined, we need to know what the full range of processes and functions are and what could potentially be altered by stressors at the appropriate scale. According to this particular framework, hydraulic regulation, regulation of water chemistry, sediment regulation, hydrologic connectivity, temperature regulation, and habitat provision should all be considered (Flotemersch, 2015). The framework provides an operational index to evaluate the levels of integrity based on the six key watershed functions listed above. Spatial information can then be used in the Spotsylvania region to help further determine some of the functions and annual water availability (Mirrah, 2017). Overall, this framework can help conceptualize the processes within the watersheds of the sPower solar sites and how they will be impacted with the implementation of the solar panels.

Prior Studies and Concerns

The local watershed of the sPower solar farm sites is supported by precipitation that occurs within the surrounding areas of Spotsylvania, Orange, Culpeper and Louisa Counties. The local residents, specifically in Fawn Lake, receive water from the Surficial Aquifer where clay beds create confined conditions for the water to settle (King, 2018). According to a GeoSeer employee and Spotsylvania County resident, if sPower were to use the local tap water during the construction stage, it would have significant impacts and possible depletion of local water reserves (King, 2018). In response, sPower decided to redesign their water usage plan for the two year construction period.

The updated plan greatly reduced their anticipated water need from what was originally estimated, 400,000 gallons of water per day (gpd), to 100,000 gpd (Waters, 2018). Even after the reduction Golder, a third-party engineering company, conducted a preliminary hydrogeologic evaluation and estimated that sPower could sustainably use at least 470,000 gpd with minimal impacts to the aquifer (Waters, 2018). However, the more recent sPower Water Use Plan commits to purchase water (max 100,000 gpd) from the county utility system instead. The change also significantly reduced the original narrative which initially estimated that 756 acre-feet of water (246,343,680 gallons) that would be used during construction (Waters, 2018). This change not only relieves the recharging and groundwater use concerns from the residents but also eliminates any additional risk of compromising watershed integrity by utilizing the aquifers.

Methods

Data

The sPower solar farm site boundaries were acquired by downloading the official site plan map produced by the Spotsylvania County Planning Department (*Figure 3*). These site shapefiles were then made available to the University of Richmond students using ArcGIS online. The site boundary was very important in conducting the entire analysis. Next, a ⅓ arc second Digital Elevation Model (DEM) was downloaded from the USGS National 3DEP Downloadable Collection in order to complete the watershed delineation. In addition, the U.S. streams and watershed boundaries were downloaded from the USGS National Watershed Boundary Dataset. The Fawn Lake polygon was extracted from the Spotsylvania County Downloadable GIS data under “Rivers and Waterbodies”. The watersheds and other streams would have also been used from their website, however, a portion of one of the sPower sites and its watershed is located within Orange County. Finally, the York River Basin boundary was digitized from the Virginia Department of Conservation and Recreation watershed map (*Figure 4*) to show the full flow route at a larger scale.

Analysis

The site boundaries, detailed in the sPower project site plan were retrieved from the Spotsylvania County Planning Department (*Figure 3*), and were then georeferenced into ArcMap and digitized into polygons. Next, Model Builder was utilized to create a workflow of tools used to delineate the watersheds within and surrounding the Project sites. The first step in the workflow was to hydro-condition the DEM using the fill tool. This ensured that if there were any sinks (flaws) within the DEM, they would be filled and the derived delineation would be continuous. To delineate the watershed the following tools were used after filling the DEM: Flow Direction, Flow Accumulation, Snap Pour Point, and Watershed.

The Flow Direction tool takes the filled DEM as the input and computes the data into a raster showing the direction of flow out of each cell. The raster output is then used as the input for the Flow Accumulation tool, which calculates the accumulated flow as the accumulated weight of all of the cells flowing into each downslope cell in the output raster. Following, the Snap Pour Point tool is used to ensure the selection of cells with the highest accumulation flow are being used when delineating drainage basins using the Watershed tool. Snap Pour Point searches within a snap distance around a specified area for cells of the highest accumulated flow and will move the pour point to that location. Finally, the Watershed tool uses the raster from the Snap Pour Point tool output to determine the contributing area (watershed boundaries) of the set of cells in the raster.

Unfortunately, the watershed, or rather basin, boundaries that were produced from this process did not delineate to a scale small enough for the purpose of this analysis. However, the watershed boundary data from USGS was able to give a more precise representation of the watersheds that exist within and beyond the boundaries of the solar farm sites. The flow points, as well as the vulnerability points of the sites, were also identified using the the USGS data.

To calculate the site percentage of contribution to the watersheds, a field was added to the attribute table of the Spotsylvania Solar Farm Sites layer, the Site Watersheds layer, and the Fawn Lake layer. The 'Calculate Geometry' function was then used on the new fields in each layer to calculate the square mileage within the different attributes. The square mileage calculated for the solar site and Fawn Lake were then divided by the total square mileage of their respective watersheds to compute the percent contribution.

Figures/Results

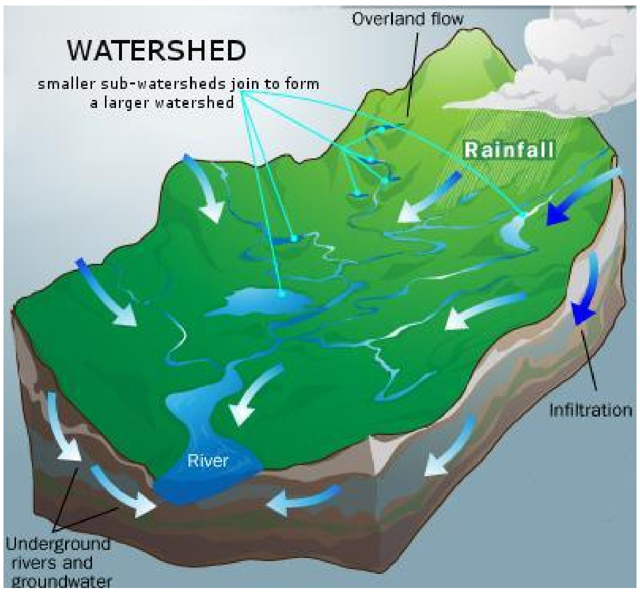


Figure 1. This infographic from the Mississippi Wildlife Federation simplifys how water flows within a watershed and all of the other important elements within it.

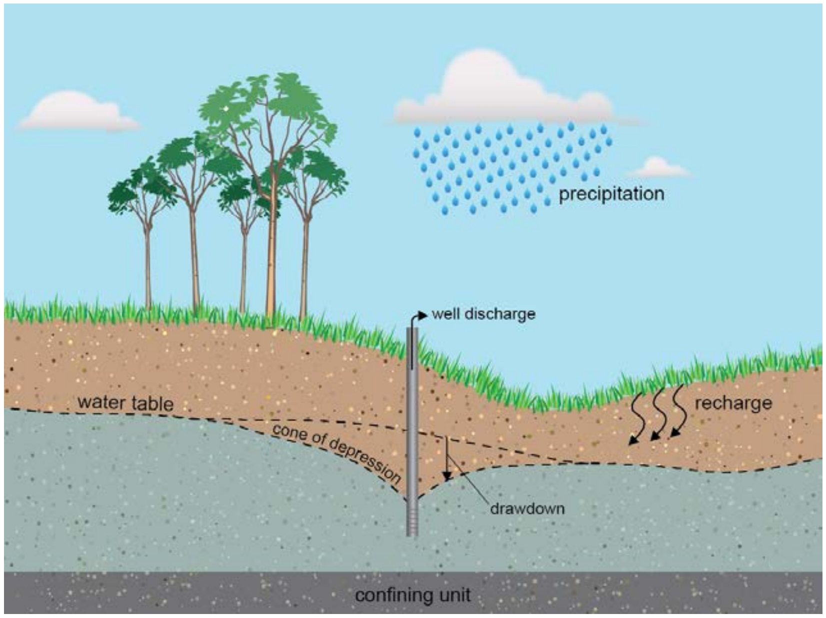


Figure 2. A cone of depression in the water table showing how drawdown and recharge work in groundwater wells (USGS Water Science School).

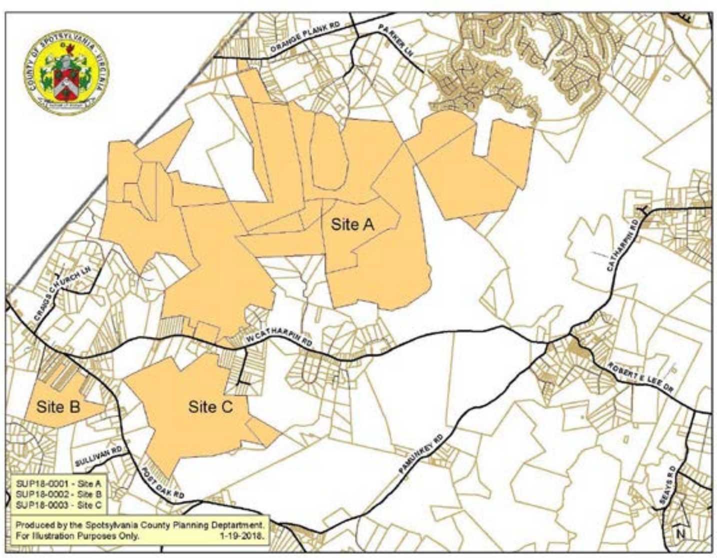


Figure 3. The Spotsylvania County Planning Department Site Plan Map

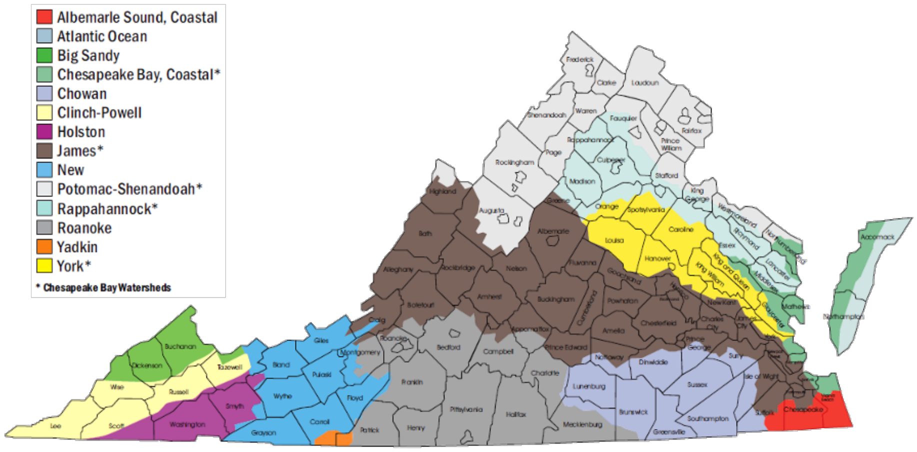


Figure 4: The Department of Conservation and Recreation Virginia Watershed map used to digitize the York River Basin.

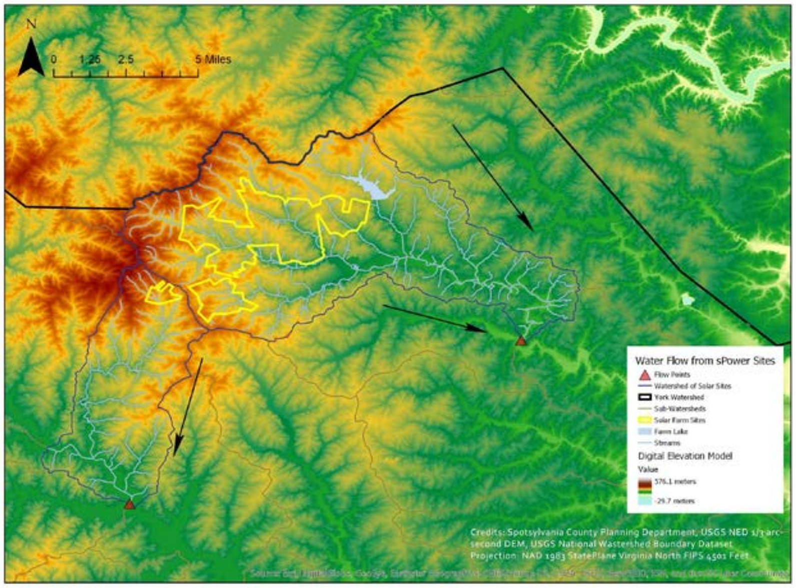


Figure 5. This is a map of the two watersheds that the sPower solar farm sites are located in, using the DEM as a reference. The black arrows are used to show direction of water flow.

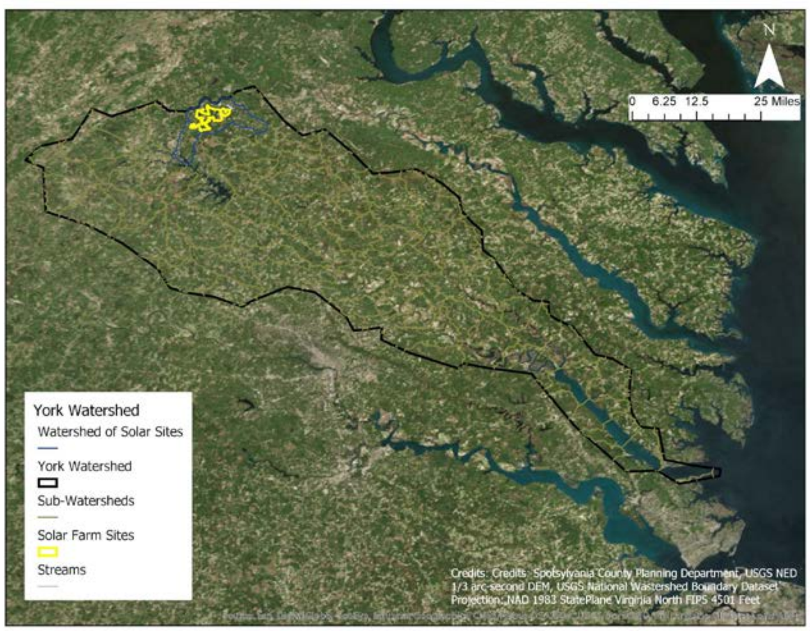
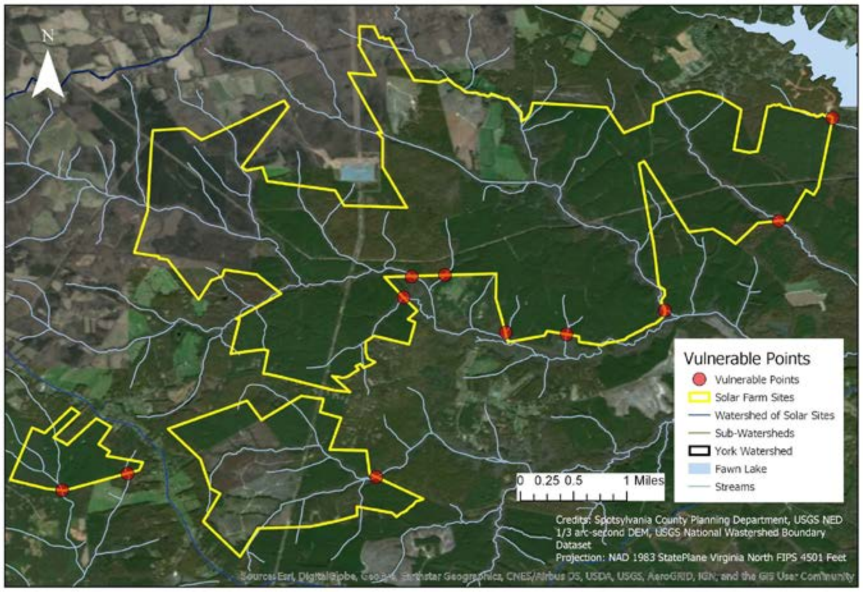


Figure 6: The sPower solar farm sites within their respective sub-watersheds in relation to the York River Basin.



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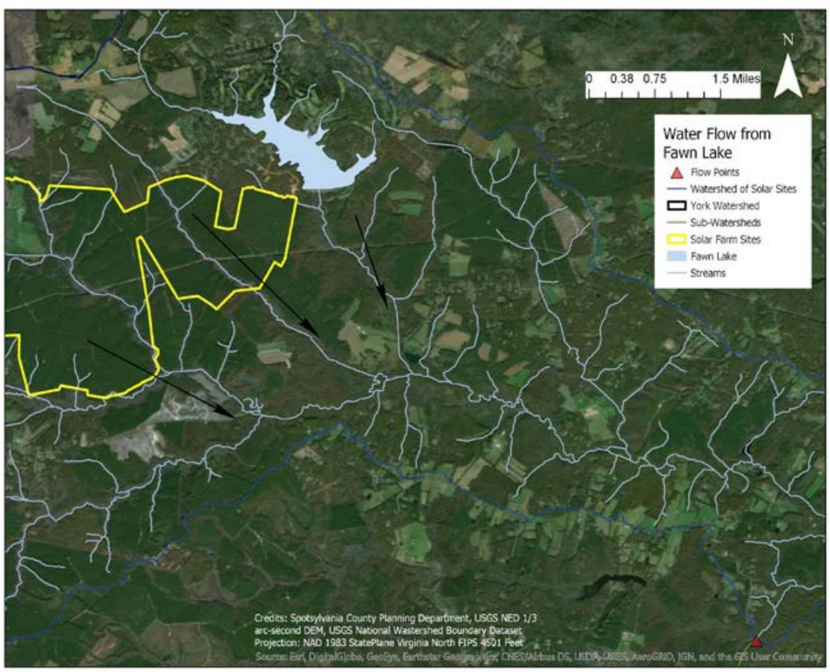

vulnerable points on the streams exiting the sPower solar farm sites.

Figure 8: This is a map showing the water flow from Fawn Lake and the waterflow from the sites entering Po River. The black arrows are used to show water flow direction.

Discussion

Using the national watershed boundary dataset and the USGS ⅓ arc second DEM, it was determined that the sPower Spotsylvania solar panel farm sites are located within two sub-watersheds, out of the eleven main sub-watersheds that exists within Spotsylvania County (*Figure 5*). The DEM is symbolized to show the highest elevation point in red, while the lowest elevation points are in light green. The highest elevation areas exist on the western side of the map, while the lowest points are the streams and rivers on the east. The change in elevation is what causes the streams and rivers to flow west to east into their respective drainage pour points.

The two sub-watersheds that contain the solar farm sites are located within the greater Virginia hydrology areas of the York River watershed (*Figure 6*). This means that all of the surface water runoff and groundwater will subsequently flow southeast into the York River from their specific drainage basins. Solar farm sites A and C are located within the same sub-watershed. Site A, the largest site, contributes to 15.9% of the sub-watershed, while Site C contributes 2.7%. Between these two sites, nine streams flow from them, creating points that will require sediment runoff, erosion, and other vulnerabilities to be monitored (*Figure 7*). The water systems from these particular sites further delineate into the Po River and connects to Glady Run at the lowest elevation, or flow point (*Figure 5*). This is important to note because endangered species have been identified in the Po River and could potentially be affected by runoff from the sites that are situated upstream. Site B, the smallest site, is within a separate sub-watershed. It is located at the northernmost section and contributes to roughly 1.9% of its sub-watershed. There are two different subsections of streams that flow directly through and off of the site, which should also be monitored for vulnerabilities as they delineate southeast into their pour point at Lake Anna.

Fawn Lake and its surrounding residents are also situated within the same watershed as Site A and C. The body of water itself contributes to 0.77% of the watershed. Fawn Lake is positioned at a higher elevation and further upstream from the solar sites. In fact, the stream that carries the water from Fawn Lake does not connect with the project site streams until they both delineate into Po River (*Figure 8*). Any sedimentation from surface water runoff would be carried away from the project sites, south of the Fawn Lake area. Fawn Lake is beyond the area of influence for the runoff and erosion concerns and therefore should not have any adverse impacts to the streams that feed into Fawn Lake.

Conclusion

In conclusion, the results of this study were not revolutionary, but rather a confirmation and summary of how the watershed could possibly be affected from the sPower solar farm project. To me, the importance of this study was understanding the methods of conducting a hydrology analysis, providing key context about how a watershed functions, and promoting the University of Richmond's efforts in sustainability outside of the campus boundaries. It was disappointing that the watershed delineation I manually created was not used as any of the main graphics within this study, however, it was an important learning process and gave me exposure to tools in ArcMap and ArcPro. If I were to continue research on the function, flow, and vulnerabilities of the watersheds potentially affected by the sPower project, I would use more of the watershed integrity theory indexes to expand my measurements.

Moving beyond this research, sPower's Erosion and Stormwater control designs are under review with Spotsylvania County, but much of what they have designed goes above and beyond county and state regulations; i.e. emptying catch basins twice as frequently, installing additional windrows and conveyance channels, and drill-seeding for stabilization (Waters, 2018). The full designs will be shared once they are finalized during the site plan stage with the County. Further, sPower plans to release the 2nd White Paper, including a Hydrology Report in response to the citizen’s comments, which will include a formal Hydrology Report. The information within this watershed study will be an effective resource to aid in the interpretation of dialog and context within the upcoming Hydrology Report.

Works Cited

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