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Environmental Management in Richmond, Virginia: A Case Study of Reedy Creek

In 2009, the U.S. Environmental Protection Agency (EPA) issued updated rules regarding Total Maximum Daily Load (TMDL) levels for three primary pollutants in the Chesapeake Bay: nitrogen, phosphorus, and total suspended sediment (TSS). Originally required under the Clean Water Act, the EPA issued these updated rules in response to former President Barack Obama's push for a cleaner Chesapeake Bay watershed.

The EPA required Richmond and other municipalities to draft Watershed Implementation Plans (WIPs) detailing individual pollution reduction goals and specific actions required to achieve those goals. The Richmond Department of Public Works (DPU) published the city's TMDL Action Plan in 2015, describing the city's intention to complete stream restoration projects on five urban streams in order to achieve necessary pollution reductions.

Reedy Creek is a stream located in Richmond's Forest Hill neighborhood (see Figure 1) and was one of the five streams included in DPU's plan. The City of Richmond commissioned a private consulting company to complete erosion analyses and recommend stream sections for restoration. The City planned to finance the project with existing funds allocated for stormwater management projects and additional money obtained through the Virginia Department of Environmental Quality (DEQ) Stormwater Local Assistance Fund (SLAF).

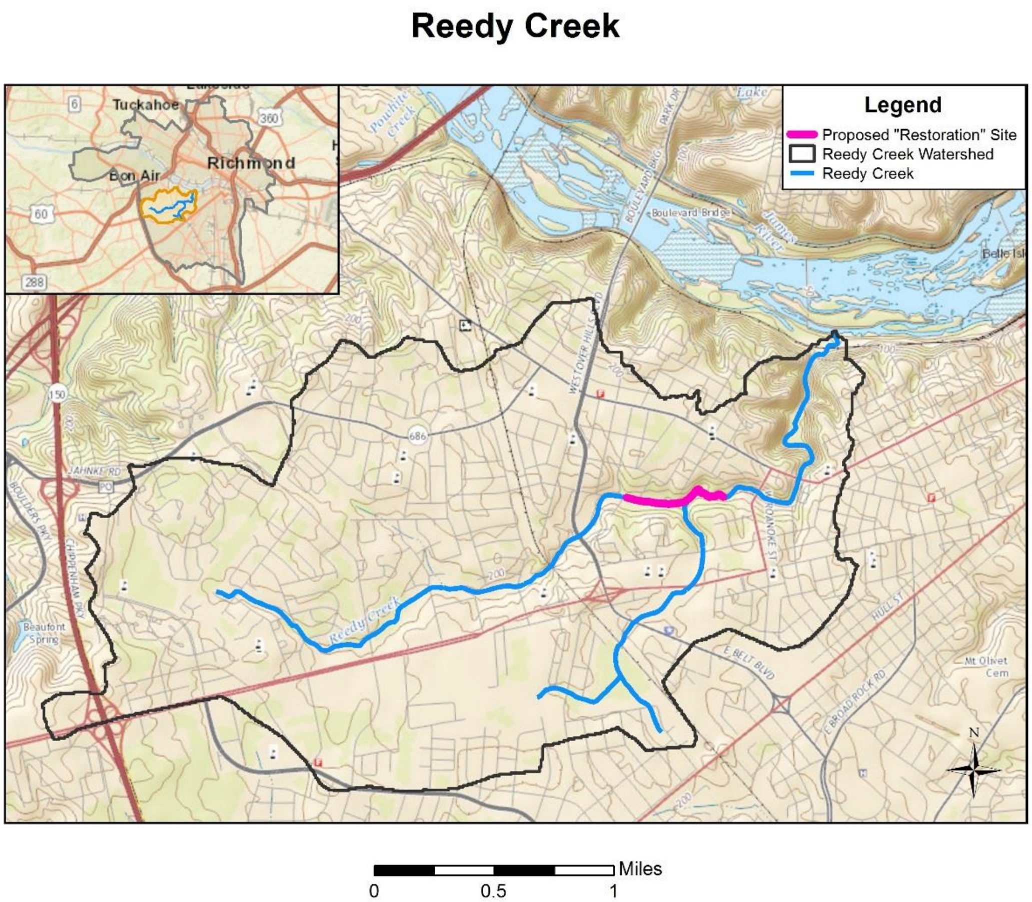

Figure 1: Map of Reedy Creek, created by Jared Goldbach Ehmer and Andrew Loesch.

The Reedy Creek restoration project faced significant opposition from the local community, particularly Forest Hill residents and members of the grassroots group Reedy Creek Coalition. Though the coalition and others raised many issues, common complaints included a lack of planning or consideration of alternative locations, an absence of watershed-level analysis and a need for a post-restoration maintenance plan. Reedy Creek Coalition amassed 821 signatures on a petition against the restoration, and at the time of this writing, the restoration has not taken place.

This report analyzes the Reedy Creek restoration project through four distinct lenses and aims to achieve a fuller understanding of the factors influencing the project's success or failure. We hope this report contributes to a greater appreciation of the complex and vast amount of decisions both cities and stakeholders make when complying with environmental regulations. Moreover, we hope to provide invaluable learning opportunities for future environmental projects undertaken in the City of Richmond.

This report is split into four sections:

Section I: The Influence of Formal and Informal Policies on the Reedy Creek Restoration

Emily Onufer

The Reedy Creek stream restoration endeavor involved numerous policy-makers and stakeholders, all of whom influenced the project's direction and outcomes. Policy was a driving force behind the project from its inception, from the EPA's formal policies governing Chesapeake Bay pollutant inputs, to the semi-formal policy-making authority of Richmond's Department of Public Works, City Council, and Planning Commission, to the informal and unspoken rules governing stream restoration projects across the United States. Though stream science is obviously central to an understanding of restoration projects like this one, policy has equally strong leverage in the restoration discipline. Many analyses, especially in the field of sociology, have debated the influence of informal groups such as nonprofits, coalitions, and consultants on formal policy-making bodies, mainly government agencies (see West 2004, Verloo 2016). This section will examine the roles and influence of the various stakeholders involved in the Reedy Creek restoration project, and attempt to analyze the influence formal and informal policy-making bodies can have on small-scale environmental management projects such as this one.

The Environmental Protection Agency's updated rules governing the Total Maximum Daily Load (TMDL) for several pollutants in the Chesapeake Bay watershed are the most formal and structured policies affecting the Reedy Creek restoration project. The Clean Water Act requires the EPA to establish these TMDL regulations, but the new 2009 rules also reflected a push from former President Obama to clean up the Chesapeake Bay (EPA 2010: ES-1). The EPA's specific responsibility is twofold: (1) establish pollution reduction targets for the entire Chesapeake Bay watershed, and (2) approve watershed implementation plans (WIPs) for individual jurisdictions, then monitor progress. In this latest iteration, the EPA set total watershed pollution limits of 185.9 million pounds of nitrogen, 12.5 million pounds of phosphorus, and 6.45 billion pounds of sediment annually, with a target completion year of 2025 (EPA 2010: ES-1). The city of Richmond, Virginia falls within the Chesapeake Bay watershed, and was therefore tasked with drafting a WIP outlining specific actions the city would take to reduce its pollution contributions.

The Richmond Department of Public Works (DPU) drafted the city's WIP, called the "TMDL Action Plan." The action plan briefly touches on residential stormwater management practices and other smaller-scale pollution reduction strategies, but focuses most prominently on the city's decision to achieve pollution reduction targets through a series of five stream restorations located within city limits (DPU 2015: ix). This analysis focuses on Reedy Creek, a James River tributary stream collecting water from a 3,075 acre watershed (DPU 2015: ix). The proposed restoration project would restore 2,200 linear feet of Reedy Creek located on city-owned land, and DPU estimates pollution reductions of 165.00 pounds nitrogen, 149.60 pounds phosphorus, and 98,736.00 pounds suspended sediment annually upon completion (DPU 2015: ix, 4-3). Though the DPU report clearly states the city's intention to meet the Chesapeake Bay TMDL requirements through stream restoration projects, the city retains the option to substitute alternative projects at its discretion (DPU 2015: 3-16, 4-2). This formal policy implementation document reinforced Richmond's authority in the restoration project debate.

Richmond hired a private consulting company, the Timmons Group, to conduct an erosion analysis and make recommendations about the "best" stream sections for restoration. Though the Timmons Group is not a formal policy-making entity, the authority conveyed in its scientific analysis of Reedy Creek allowed the city of Richmond and other stakeholders to treat the consultants' analysis as a formal policy recommendation. The Timmons Group evaluated a diverse set of stream factors including "the potential for existing wetlands adjacent to the Reedy Creek stream reach that would need to be avoided with a wetland creation design, the need for undesirable impacts to the existing mature forested community to construct these wetlands, and the potential for utility conflicts" (Timmons Group 2015: 3). The report amassed a significant amount of field work and professional knowledge, and the recommendations within were almost wholly adopted by the city of Richmond for the remainder of its planning process.

The Richmond City Council and Planning Commission, two branches of Richmond City Government, hold responsibility for policy facilitation and implementation. The Planning Commission reviewed an ordinance on September 19th, 2016 outlining a $1,270,000 budget for the Reedy Creek restoration - $635,000 each from the Richmond Stormwater Utility and a Stormwater Local Assistance Matching Fund grant from the Virginia Department of Environmental Quality (Planning Commission 2016). The ordinance was forwarded to the City Council, with an approval recommendation from the Planning Commission. The City Council reviewed the ordinance on September 26th, 2016, but declined to make a decision at that time (City Council 2016a). On November 14th, 2016, the City Council once again reviewed the ordinance and declined to accept the grant funding (City Council 2016b), putting a temporary pause on the Reedy Creek restoration project.

Informal policies also affected the Reedy Creek stream restoration, the most prominent of which was Dave Rosgen's Natural Channel Design (NCD). NCD is widely considered the best available stream restoration method in the United States today. Many companies will only consider project proposals containing NCD, and several federal agencies have adopted NCD and excluded all other methods (Lave 2012: vii). Rosgen's company, Wildland Hydrology, has implemented over 70 large-scale restoration projects to date (Rosgen 2017). NCD has two main phases: classification and restoration. Streams are first classified "into alphanumeric categories based on features such as their slope, sinuosity, relationship with the floodplain, width:depth ratio, and bed material" (Lave 2012: 33). In the restoration phase, boulders and tree trunks placed in the stream provide stability and prevent future erosion (Lave 2012: 1). Despite its widespread use across the United States, academics vocally critique Rosgen's approach (see references in Lave 2012), and available evidence cannot conclusively determine whether Rosgen's methods actually work.

NCD permeated the Reedy Creek restoration project from start to finish. The Timmons Group report's introduction states clearly: "To evaluate the pollutant load coming from stream bank erosion it is recommended to use the Bank and Nonpoint Source Consequences of Sediment (BANCS) Model developed by Dr. David L. Rosgen (2001). This model is a part of the EPA's technical tools for watershed assessment of River Stability and Sediment Supply (WARSSS) developed by Dr. Rosgen, for stream restoration practitioners to use in evaluating streams and rivers impaired by excess sediment" (Timmons Group 2015: 1). On Monday, February 27th, 2017, Reedy Creek Coalition member Bill Shanabruch gave this research group a tour of the proposed project site, and mentioned NCD during the tour, demonstrating just how ingrained the NCD methodology has become in this particular restoration project.

Though it seems the restoration project has been driven solely by formal policies, informal groups with the ability to affect policy have been instrumental as well. The Reedy Creek Coalition is a grassroots group, composed mainly of Forest Hill neighborhood residents, who are passionate about protecting their neighborhood's natural spaces. The coalition is not a formal policy-making entity, and has less geographic reach than any other stakeholder discussed thus far. Despite these barriers, the coalition's opinions and recommendations influenced the restoration project nearly as much as the formal documents produced by the Timmons Group, city government, and Dave Rosgen. The coalition is far-reaching in the Forest Hill neighborhood. On November 14th, 2016, the coalition presented City Council with an 821-signature petition against the restoration project (RCC 2016a). Primary critiques included a lack of planning, particularly with regard to site selection, a failure to consider alternatives, especially non-stream-restoration alternatives, an absence of watershed-level analysis, and a need for a post-restoration maintenance plan. After receiving the petition, City Council declined to accept the grant funding necessary for the project's immediate commencement, and it seems the coalition is at least partly responsible for this significant halt in progress.

Despite the Reedy Creek Coalition's organized resistance to the restoration project, other stakeholders sometimes dismiss or ignore the coalition's opinions. In this way, the coalition has had a muted influence on the Reedy Creek restoration project, despite holding the biggest stake in the project's outcome. City government in particular has not fully cooperated with the coalition's requests, as evidenced by the coalition's multiple Freedom of Information Act (FOIA) requests filed for city-generated documents. The coalition has also not always operated within the city's procedures and deadlines, however. For example, the coalition submitted comments on DPU's original TMDL action plan detailing specific concerns, but the comments were submitted late. DPU included the following statement towards the end of the final published TMDL action plan: "We did receive comments on September 21, 2015 from the Reedy Creek Coalition (www.reedycreekcoaltion.org) with concerns about the ultimate success of the stream restoration in Reedy Creek. Even though the comments were received outside the allotted public comment period, the city provided a response to the organization and since we are a partner with them in analyzing the samples collected in the creek, we hope that we can address the concerns expressed by them with future communication on the stream restoration" (DPU 2015: 5-1). Communication between the coalition and the city has clearly been inadequate at times.

The Reedy Creek Coalition has admirable objectives, and undoubtedly would like the city to consider non-stream-restoration alternatives to meet the EPA's Chesapeake Bay TMDL regulations. Political economist Elinor Ostrom's common pool resource theory describes the potential for self-generated stakeholder groups such as the Reedy Creek Coalition to serve as effective custodians of otherwise ungovernable resources, such as Reedy Creek. Ostrom proposed eight principles for effective, local self-government of common pool resources (Ostrom 1990):

(1) the group must have clearly-defined boundaries,

(2) the rules established to govern the resource must be adapted to the local conditions,

(3) people affected by the rules must be able to participate in an established process for changing the rules,

(4) the group must be respected by the relevant authorities,

(5) the group must establish systems for monitoring the behavior of its members in regards to the common pool resource,

(6) rule violators must face sanctions,

(7) dispute resolution must be available at low cost to members, and

(8) responsibility for governing the common pool resource must be integrated at every level, from each individual person to the entire interconnected system.

The Reedy Creek Coalition could benefit significantly from an evaluation of Ostrom's (1990) principles, and potentially achieve their goals for Reedy Creek in the process. The coalition successfully fulfills principles one, two, five, and eight through clearly-defined goals and membership qualifications (RCC 2017a) grounded in a local context (RCC 2017b), in-depth stream monitoring activities and residential watershed assessments evaluating the environmental impact of homeowner behaviors (RCC 2017c, RCC 2017d), and consistent reference to Reedy Creek's influence on the Chesapeake Bay watershed (RCC 2017e). Despite these clear successes, the coalition falls short on principles three, four, six, and seven. Though the coalition holds monthly meetings (RCC 2017f), processes for dispute resolution, rule modifications, and sanctions are not clearly established in any of the coalition's available publications. In addition, local authorities do not consistently respect the coalition's governance. After years of voiced concerns, grassroots organizing, constant presence at city government meetings, and a victory in the City Council's rejection of available grant funding, the city of Richmond nonetheless applied for a federal permit for the stream restoration work at Reedy Creek in February 2017 (Oliver 2017). Though the restoration still has not taken place as of this writing, Reedy Creek's future remains unclear.

The Reedy Creek project is an interesting case study for how the city of Richmond manages its natural assets and responds to environmental regulations, but it is just one example. A simple key word search of Richmond City Council agendas reveals the city's lack of attention to water issues. I executed a word search for three key terms – "Reedy Creek," "Chesapeake Bay," and "water" – in 102 Richmond City Council agendas comprising the full years 2015, 2016, and 2017 to-date. None of these terms appear on more than 29% of City Council agendas in any given year in the search range (see Figure 2). Though newly-elected President Trump may reverse the Chesapeake Bay TMDL regulations, Richmond has a real opportunity to surpass federal environmental legislation and make significant strides in the realm of water pollution and degradation. Unfortunately, this key word search suggests the city has not made urban water protection a priority.

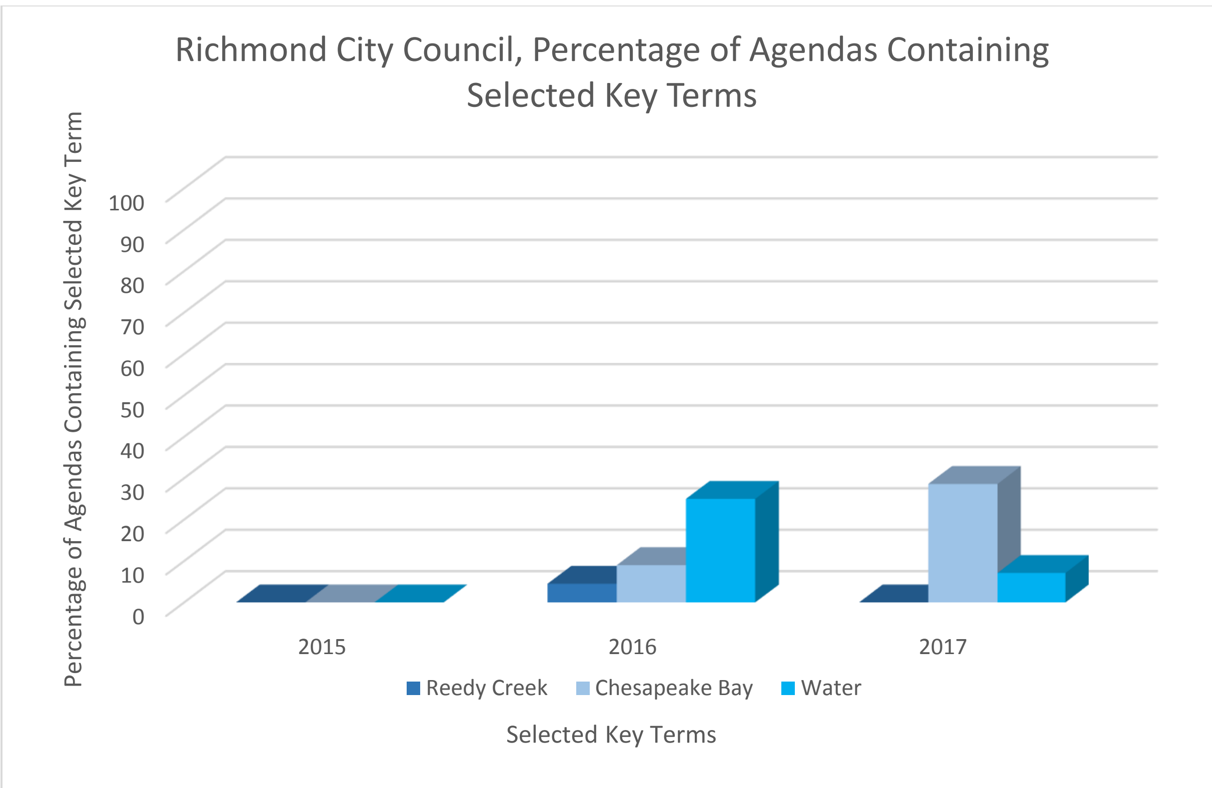

Figure 2: Key Term Research, Richmond City Council, 2015-17. Produced by Emily Onufer.

The Reedy Creek restoration project involved numerous stakeholders, each with varying levels of formality and influence over the project's outcome. The U.S. Environmental Protection Agency issued updated regulations for pollution entering the Chesapeake Bay, and the city of Richmond Department of Public Works drafted a city-scale implementation plan specifically to meet those regulations. Formal environmental policy, therefore, drove the entire restoration project, from inception through implementation. Richmond commissioned a private consulting company, the Timmons Group, to conduct a scientific analysis of erosion potential and make formal recommendations for best-candidate stream restoration sections. The Timmons Group's final report was treated as a formal policy recommendation, despite its actual status as one company's interpretation of a dynamic, complex stream system situated in an even more complex urban environment. The Planning Commission and City Council facilitated the financial and logistical implementation of the project, and pressure from the grassroots Reedy Creek Coalition influenced these governing bodies' decisions. Unspoken rules of convention, particularly Dave Rosgen's Natural Channel Design methodology for stream restorations, permeated every step of the Reedy Creek project. Despite holding less formal authority than the EPA, all of these other stakeholders had a significant impact on the restoration efforts.

The Reedy Creek stream restoration was much more controversial than any of the other four proposed restorations mentioned in the DPU report, and it begs the obvious question: why? No other stream had a neighborhood group nearly as dedicated, passionate, and organized as the Reedy Creek Coalition. The coalition, lacking any formal policy-making authority, was able to influence a project almost entirely controlled by formal policy-making authorities because of this dedication. Though city government does not always respect the coalition's influence, and though more formal internal governing policies would strengthen the coalition's power, the coalition's accomplishments are certainly impressive. If Richmond authorities ultimately choose to abandon the Reedy Creek restoration project, the city may look back on this experience as an example of poor planning, inadequate communication, and unrealistically simplified environmental management. Richmond is a rapidly-growing city, and should be doing everything in its power to cultivate the talent, knowledge, and passion already present here. Better policies for city-resident communication and improved processes for evaluation of environmental restoration, conservation, and preservation projects would certainly be a step in the right direction.

Section II: Situating Reedy Creek into the Literature of Stream Restoration

Andrew Loesch

Often surrounded by controversy, stream restoration projects face a variety of challenges associated with biological processes on local, watershed, and regional scales. Defining goals, setting restoration parameters, and ensuring the success of a project remains a difficult process, in large part due to consensus on a dedicated restorative process and careful, critical study of restorative projects. Situated at the center of local controversy, the Reedy Creek restoration project finds itself at the intersection of national policy, local stream health, and the interests of an engaged community. According to Phillip Roni and Tim Beechie (2013) of the National Marine Fisheries Service in their book *Stream and Watershed Restoration*, healthy stream restoration projects require a multi-step process including analyses, design, adjustment, and implementation of project goals. Using this comprehensive methodology as a template for a healthy stream restoration project, this section aims to explore the biological and geological risks and challenges associated with the Reedy Creek restoration project and assess the overall quality of the proposal.

A variety of physical, chemical, and biological processes spanning a wide range of spatial and temporal scales support and drive riverine ecosystems, requiring impactful stream restoration projects to adopt a multiscalar approach to establishing goals. In developing and implementing stream restoration projects, Roni and Beechie (2013) suggest a hierarchy of natural processes reliant on relative spatial and temporal scale. At the top of the hierarchy, spanning the greatest spatial and temporal scale, geological processes like tectonic activity determine landscape and basin geography on regional and national scales. Regional and local processes characterize the next hierarchical rung, comprised primarily of hydrological and lithospheric processes such as surface erosion, subsurface flow, and precipitation regime. A shift from primarily physical and chemical processes to biological processes characterizes the next hierarchical layer, as locally scalar riverine and riparian processes, according to Roni and Beechie (2013), involve primarily plant growth, dispersal, and health. Biological processes pertaining to wildlife, particularly fish and crustaceans, characterize the final layer of Roni and Beechie's (2013) theoretical hierarchy of natural riverine processes.

Comparison of a restorative project's goals to Roni and Beechie's (2013) theoretical hierarchy of natural processes may constitute a preliminary assessment of the health and impact of the proposed project. Despite criticism from local groups such as the Reedy Creek Coalition, the proposed Reedy Creek restoration initially fulfills two of the hierarchical layers. Adherence to national policy to restore the health of the Chesapeake Bay by reducing incoming sediments and pollutants qualifies the Reedy Creek restoration project goals as considering one of the hierarchical layers described as regional and national hydrological processes driven by topography. Additionally, initial focus on the vulnerability of soils at the stream to erosion suggest the primary concern of the restorative project falls under the second hierarchical layer. Although the project proposes solutions within the upper two hierarchical layers of natural processes, consideration of local and stream processes in the goals of the restoration become convoluted and complex. For example, though the project requires forest removal for machinery transport and stream maintenance, the final goals indicate an intention to replant trees in the deforested area. However, failure to provide a specific procedure for replanting (DPU 2015) and exhibited concerns for dispersion of invasive species or replanting failure caused by extreme weather events (RCC 2016a) muddles the intentions of goals associated with the third hierarchical rung. The project's engagement with the final hierarchical layer suffers from the same difficulties, ultimately failing to address risks with habitat and invasive species, likely foregone to maintain focus on soil erosion and stream velocity.

Organized using the hierarchy of physical, chemical, and biological processes, Roni and Beechie's (2013) stream restoration methodology follows several steps: watershed inventory, watershed assessment, restoration plan design, and implementation and monitoring. Watershed inventory entails the initial site selection, with consideration to multiscalar connections and policy requirements. By selecting Reedy Creek and several other streams within city boundaries for restoration in accordance to national policy under the Clean Water Act, the City of Richmond successfully completed the first step to formulating a coherent restoration project by Roni and Beechie's (2013) standards. The next step, watershed assessment, involves the analyses of natural resources and processes within the designated stream or area to identify problems with stream health, their sources, and potential solutions. As city officials contracted third-party consultants to conduct analyses on Reedy Creek, city planning officials made motions to complete the second step. However, issues arise with the completion of the watershed assessment, as results contained within soil analysis reports contradict the results communicated by city officials. In essence, the health of the Reedy Creek restoration project begins to falter with the transition from the second step, watershed assessment, to the third step, restoration plan design. The restoration plan thus began the design phase focusing almost entirely on overstated soil erosion potential, contaminating the health of the project for restoration of natural physical, chemical, and biological processes in the stream. Evidence of overstatement of the risk of soil erosion along the bed of Reedy Creek becomes evident when comparing soil analysis documents obtained legally via Timmons Group and city documentation of project justifications and final goals. Although the project has stalled with plans for its discontinuation, issues with the design and implementation phases already plagued the project before its execution. In particular, the project failed to consider alternatives to stream restoration to reduce TMDL levels running into the Chesapeake Bay. Though a variety of alternatives exist, reduction of impervious surface to reduce runoff, implementation of natural biological barriers such as marshes for water purification, and modification to the concrete channel area to reduce stream velocity appear the most attractive logistically and economically. We performed an analysis for impervious surface reduction within the Reedy Creek watershed using i-Tree Hydro and ArcGIS (these analyses are explicated further in Section III). Figure 3 below displays 1-meter Land Cover over the Reedy Creek watershed, which serves as the extent for the runoff GIS analysis.

Figure 3: Land Cover in the Reedy Creek Watershed. Created by Jared Goldbach Ehmer and Andrew Loesch.

However, miscommunication of soil erosion data and failure to consider alternatives constitute only two of many risks common to stream restoration applicable to Reedy Creek. In addition to soil erosion, the removal of barriers to invasive species establishment and dispersal would be irreversible consequences of poor stream restoration design (Grimm et. al 2008). Invasive species have the propensity to infiltrate and dominate vulnerable ecosystems. In general, stream restoration projects increase the vulnerability of riverine ecosystems temporarily between the removal of vegetation and the re-establishment of vegetation and associated riparian habitats (Bond and Lake, 2003). Reedy Creek acts as no exception, as removal of approximately four hundred trees for machine thoroughfares increases the vulnerability of local terrestrial ecosystems to invasion by invasive vegetation, disease, and insects. Several invasive species are already established in the Reedy Creek watershed that threaten to overtake native species if afforded the appropriate opportunities. English Ivy, for example, requires preventative maintenance even under current circumstances. Particularly quick to expand its tendrils, English Ivy poses a threat to both currently forested areas and the development of new forested areas in landscapes. Removal of trees without appropriate efforts to control English Ivy immediately and throughout the process of reforestation could pose a major threat to the riparian and forest habitats adjacent to Reedy Creek. The city and the Timmons Group only counted mature trees above a certain width when calculating the total number of trees that would be lost in the restoration process. This clever wording indicates an ignorance to the potential risks associated with terrestrial invasive species. Although the Reedy Creek Coalition asserts that upwards of four hundred trees will be removed during the construction and clearing stages of the project (Bill Shanabruch, personal interview, 2017), similar numbers do not exist in city documents (DPU 2015). In city documentation, only trees with a width of four feet or more are counted towards the tree removal count, although several species within the area do not often reach the appropriate width even in maturity. Additionally, challenges to stormwater management and temporarily increased susceptibility to storm-related erosion pose threats not only to the success of restoration projects, but also to the health of the related ecosystems (Borsuk, Stow, and Reckhow, 2002). Efforts to subvert stormwater upstream remain evident with the concrete channel of Reedy Creek. Figure 3 displays the location of the concrete channel using a pink line overlaying Reedy Creek. Surrounding land cover displays significant urban development and impervious surface cover, logistically explaining the need for a concrete channel to reduce localized flooding and runoff. However, storm events challenge restoration projects by threatening to thwart vegetation attempting to re-establish after mechanical modifications to stream banks. As, according to the document divulged by the Timmons Group (2015) regarding bank soil erosion risk along Reedy Creek, the majority of the stream currently stands a low risk of erosion, mechanical modification and subsequent exposure to heavy precipitation or storm events risks damaging healthy soils. Additionally, removal of trees risks erosion in the adjacent terrestrial environment, with no contingency plan provided in the restoration proposal.

Section III: A GIS Analysis of the Reedy Creek Basin

Jared Goldbach Ehmer and Andrew Loesch

The Reedy Creek Stream Restoration debate sparked a search for project alternatives. Why did Richmond officials choose Reedy Creek, given the Timmons Group stream and bank analysis conclusion of an 'overall not cost-effective' stream to restore (Timmons Group 2015)? Are there better alternatives to the Reedy Creek restoration that missed consideration? This spatial analysis examines several potential alternatives to achieve Total Maximum Daily Load reductions in light of the Reedy Creek stream restoration endeavor coming to a legal halt. This section will examine the relation of spatial stream statistics and Land Cover Management practices over the current scenario and the alternative planned scenarios using the spatial statistics program iTree Hydro (Davey 2017). iTree Hydro is a "simulation tool that analyzes how land cover influences the volume and quality of runoff. It can analyze historical or future hydrological events and allow the user to contrast runoff volume and quality from existing Land Cover (referred to as the Base Case) with runoff from the Alternative Case Land Cover" (Davey 2017, Program Home Page).

The original phase of this spatial analysis focused on the delineated watershed for the point on the river reach of the Reedy Creek stream system just before it converges with the James River. This provided a Reedy Creek-specific study area where any drop of water falling within that polygon would eventually end up in Reedy Creek and exit into the James River

(Figure 4).

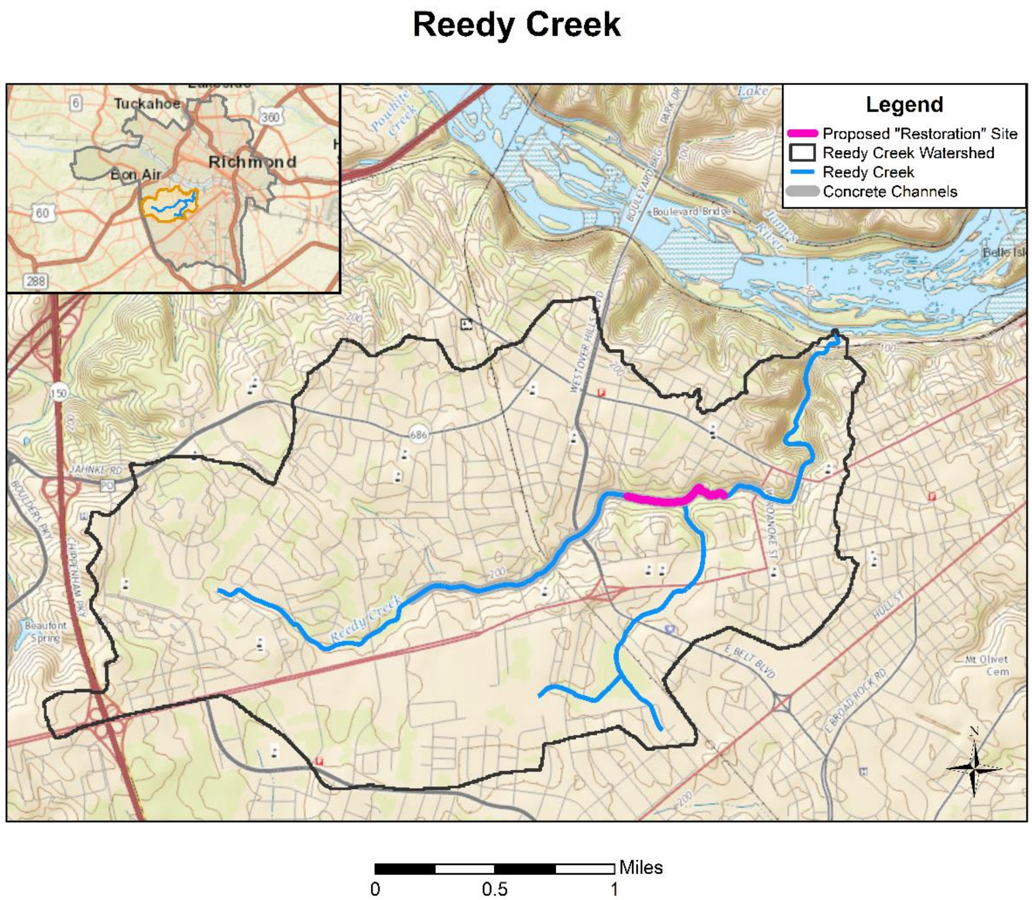

Figure 4: Reedy Creek Overview Map. Created by Jared Goldbach Ehmer and Andrew Loesch.

We chose the scope of the Reedy Creek watershed because it was the focus of the initial stream restoration effort, as shown in purple in Figure 3. We calculated Reedy Creek watershed delineation geometries and basin characteristics using the US Geological Survey's (USGS) StreamStats tool (US Geological Survey StreamStats; ESRI 2016) (Figure 4). This Land Use and Land Classification (LULC) data was then entered into iTree Hydro so that the tool could calculate the modeled statistical computations. iTree Hydro describes the 'Base Case' as the present or current situation over the landscape (Davey 2017). This Base Case is the control group and ‘current scenario’ for streamflow, runoff, pollution, and erosion (Davey 2017). Using elevation data from a Digital Elevation Model (DEM), watershed extent and basin characteristics from the USGS’ StreamStats tool, and hourly weather data for the past nine years, we calculated the modeled streamflow (Figure 5), runoff (Figure 8), pollution (Figures 12 and 13), and erosion (Figure 11) using the iTree Hydro accumulation functionality (MRLCC US Conterminous Canopy Cover; MRLCC US Conterminous Land Cover; USGS Digital Elevation Model; ESRI 2016).

Now that we have a statistical model of the current state of the Reedy Creek watershed, we analyzed potential alternatives to explore their impacts in the watershed. When setting goals for alterations to land use proportions over a period of a few years, it is common practice for municipalities to propose about ten percent of developed areas for transitions (Lambin et al. 2001). To explore if this would be a viable alternative for the Reedy Creek restoration, we analyzed these same spatial statistics on the premise of the Land Cover in the region by changing ten percent of the Developed Land (all categories of Developed Land were grouped together due to iTree Hydro input data restrictions) to Shrub. The iTree Hydro Program does not allow for specific areas of Land Cover to be addressed, so the ten percent Developed-Shrub change is randomly and uniformly applied across the watershed study area. If there is higher permeability surrounding Reedy Creek, runoff may be reduced, but the potential reduction in peak streamflow in severe weather events may result in a decrease in erosion (Figure 7). This would assist in accomplishing the goal of Richmond’s Watershed Implementation Plan to reduce Total Suspended Sediment as mandated by the Clean Water Act (EPA 2010). If this alternative to the planned stream restoration of Reedy Creek were to be implemented, it would achieve the same result, but through a different means. However, one of the relative benefits is that with the potential risk of the stream restoration being washed away because of the streamflow speed of the upstream concrete channel, the proposed alternative project is significantly less risky. Under the proposed alternative plan, the following stream statistics are influenced in the Reedy Creek watershed:

1. Reduction in predicted Streamflow (Figure 7). Streamflow is reduced across the time range as well as it is reduced in greater percentages during larger rain periods. This means that precipitation fluxes will be smoothed out – felt less in magnitude and rapidity.
2. Reduction in pollution loads of Total Suspended Sediment, Nitrogen, and Phosphorus (Figures 11, 12, and 13). Due to the greater filtering of the water through the increased permeable surface and decreased impermeable surface, fewer pollutants would theoretically make their way straight into the river.
3. Reductions in Impervious and Pervious flows (Particularly higher percentile reductions appear in severe weather events – floods are felt lesser in magnitude and suddenness) (Figure 10)
4. Potential reduction in erosion through the reduction in streamflow at both average and peak flow periods (Figure 7) (Note that in the comparison of Figures 5 and 6, summarized in Figure 7, there is a fluctuating influence of the aggregately modified Land Cover, but that during large precipitation events, the percentage and absolute numerical changes grow)

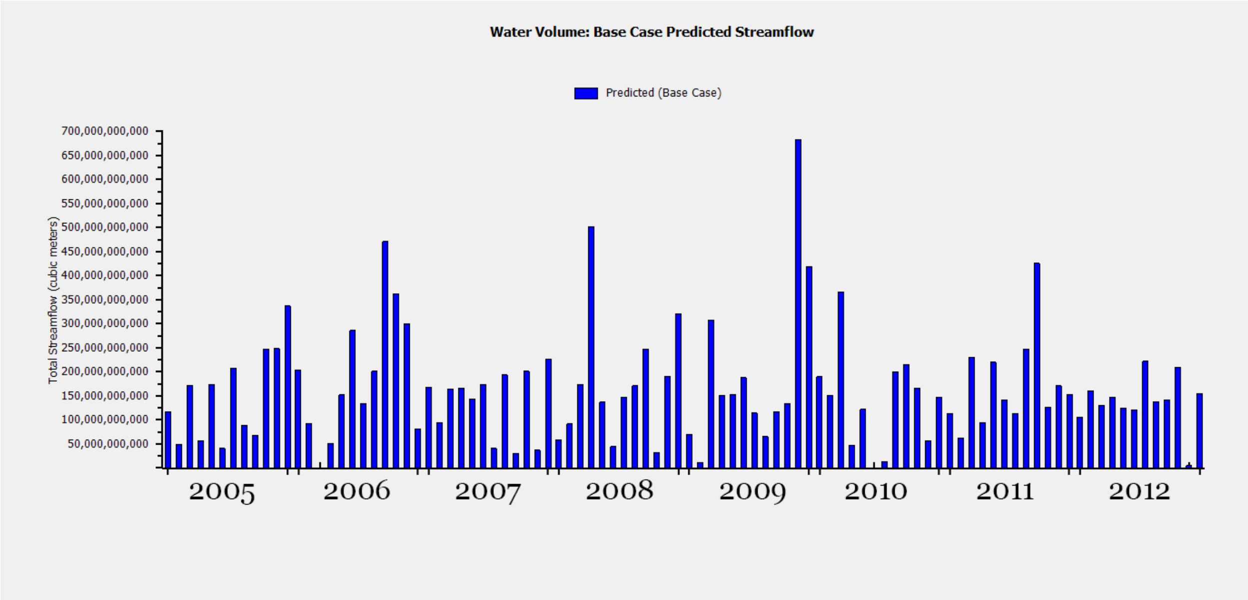

Figure 5: Base Case Predicted Streamflow. Created by Jared Goldbach Ehmer and Andrew Loesch.

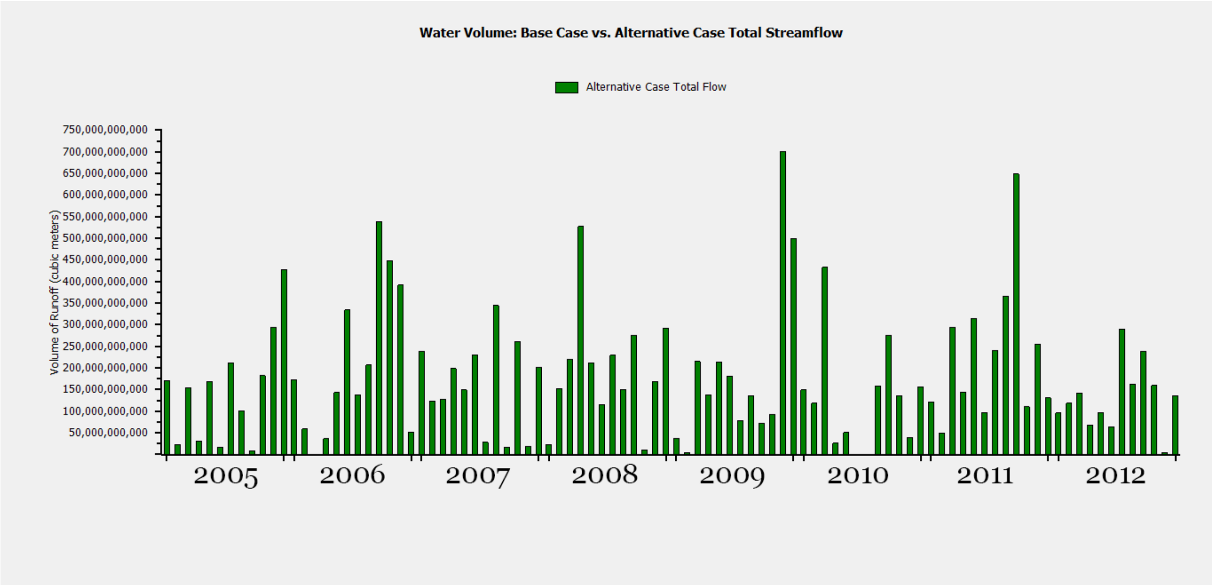

Figure 6: Alternative Case Predicted Streamflow. Created by Jared Goldbach Ehmer and Andrew Loesch.

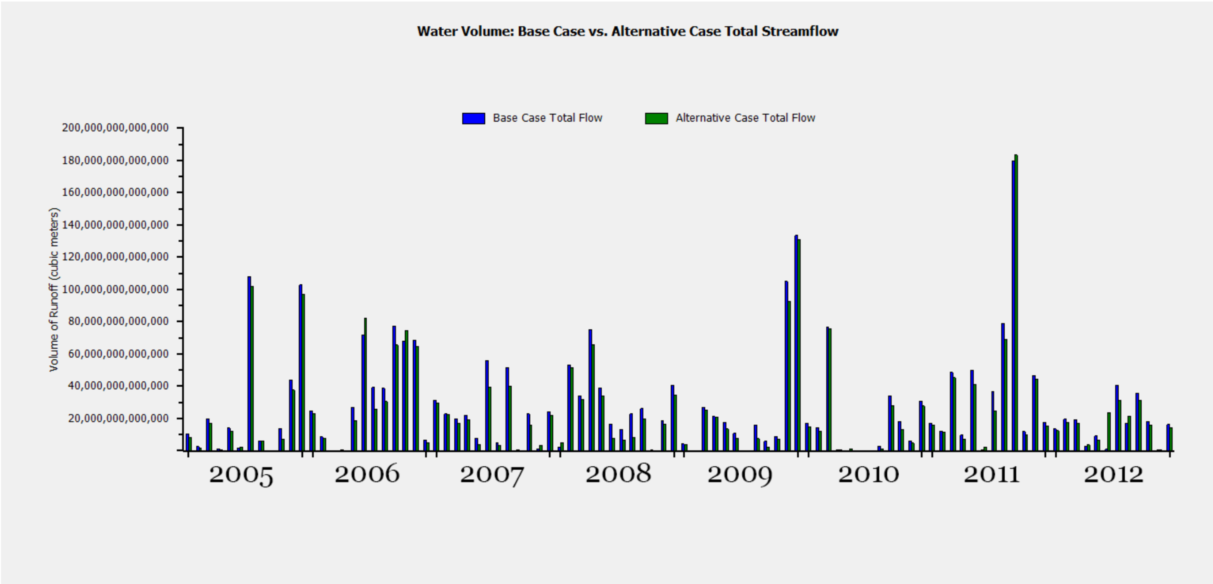

Figure 7: Base Case and Alternative Case Predicted Streamflow. Created by Jared Goldbach Ehmer and Andrew Loesch.

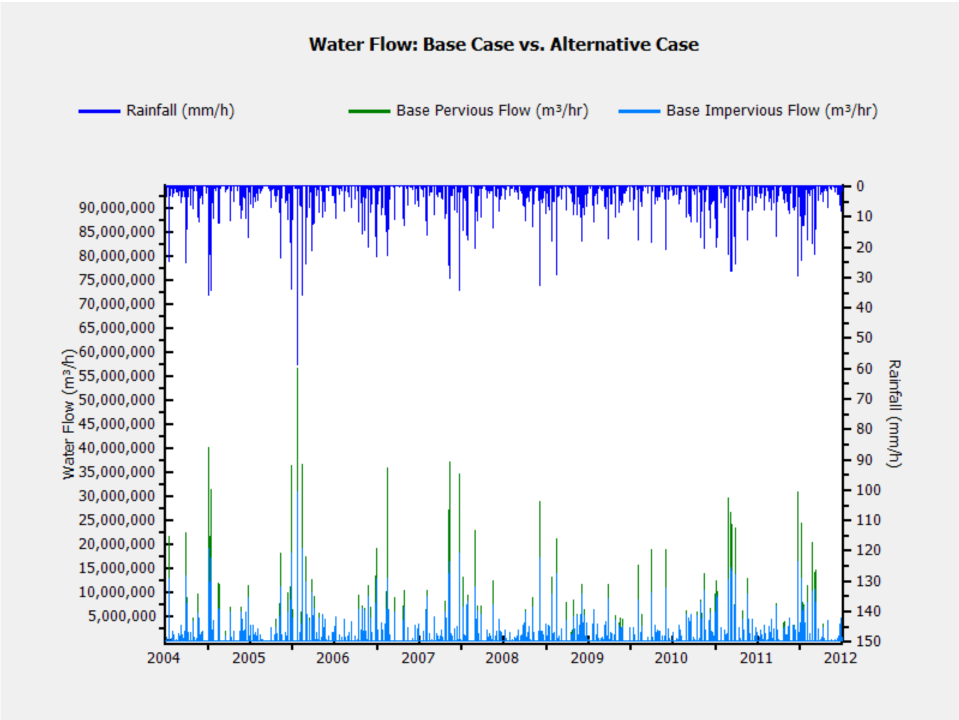

Figure 8: Base Case Impervious and Pervious Flow. Created by Jared Goldbach Ehmer and Andrew Loesch.

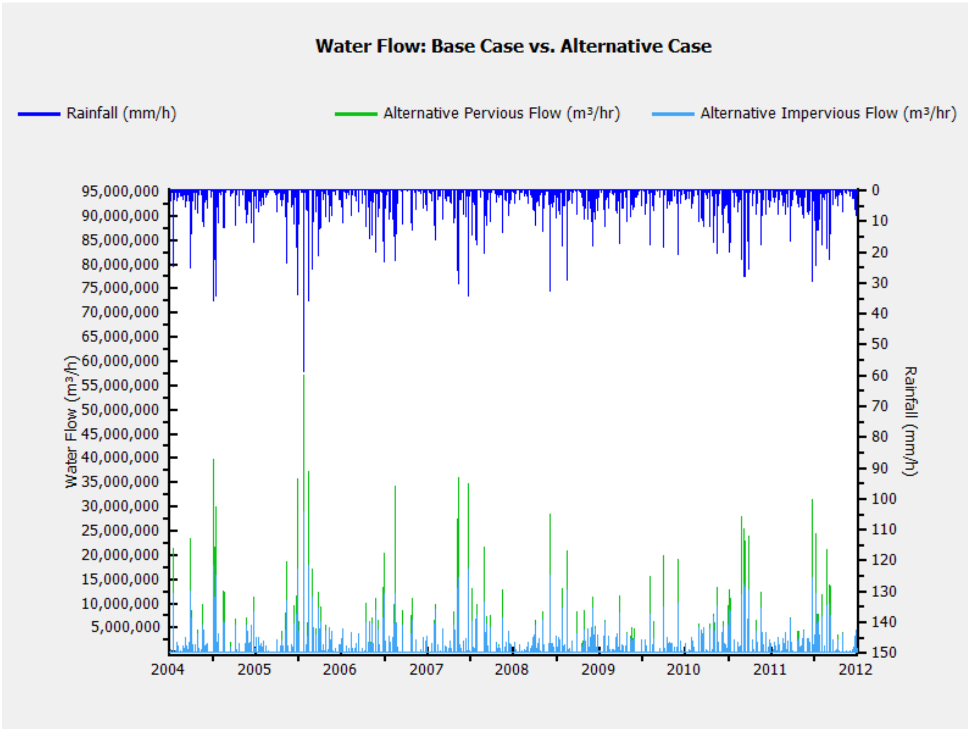

Figure 9: Alternative Case Impervious and Pervious Flow. Created by Jared Goldbach Ehmer and Andrew Loesch.

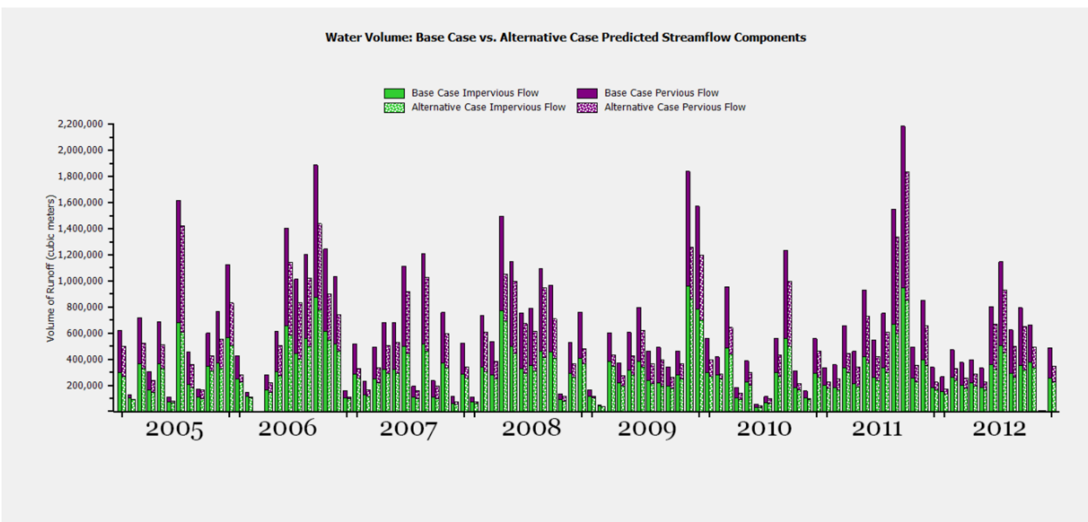

Figure 10: Base Case and Alternative Case Impervious and Pervious Flow. Created by Jared Goldbach Ehmer and Andrew Loesch.

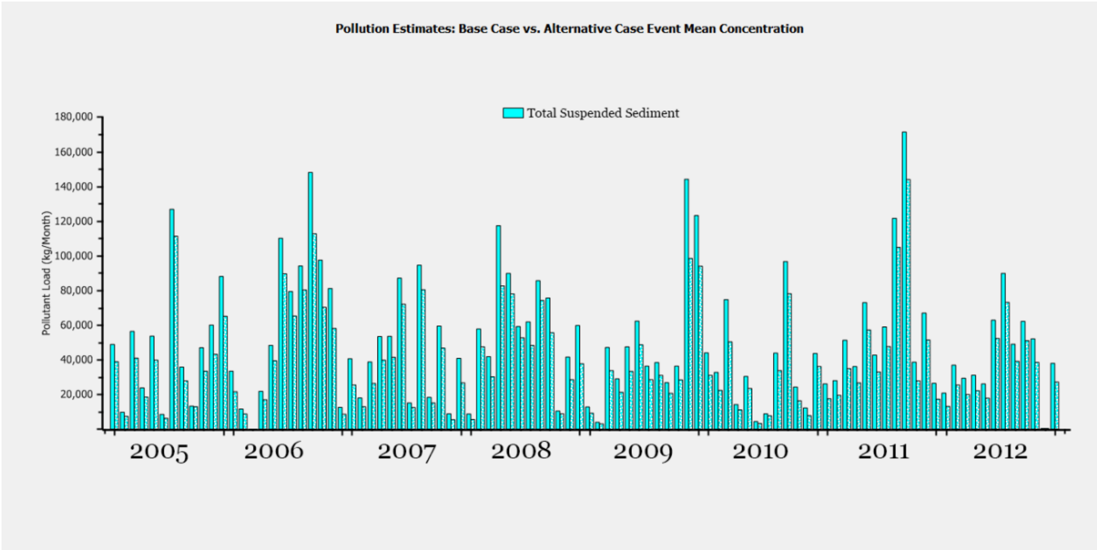

Figure 11: Pollution: Total Suspended Sediment. Created by Jared Goldbach Ehmer and Andrew Loesch.

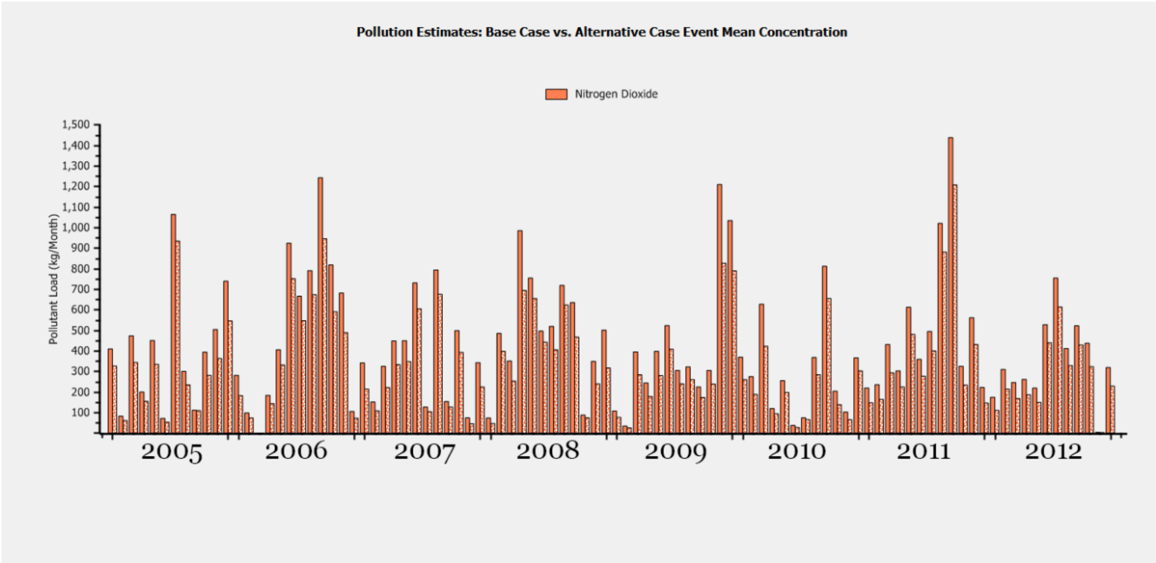

Figure 12: Pollution: Total Nitrogen. Created by Jared Goldbach Ehmer and Andrew Loesch.

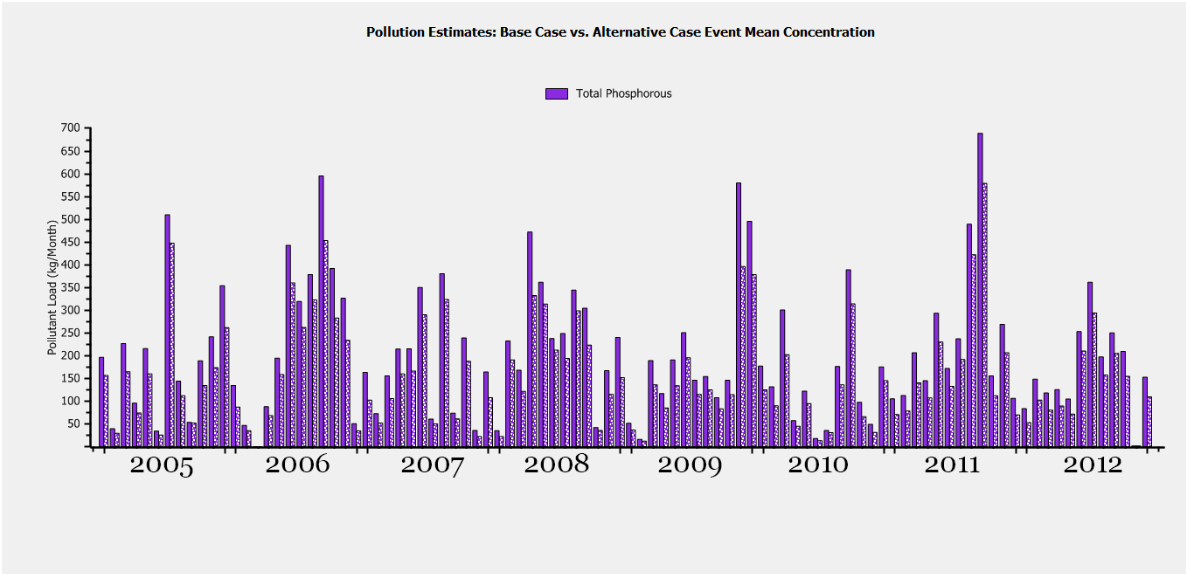

Figure 13: Pollution: Total Phosphorus. Created by Jared Goldbach Ehmer and Andrew Loesch.

Richmond must abide by the regulations of the Clean Water Act and thus reduce its (1) Total Suspended Sediment (TSS), (2) Total Nitrogen (TN), and (3) Total Phosphorus (TP) loads that reach the Chesapeake Bay (EPA 2010). Reedy Creek, seven percent of the footprint of Richmond, was one stream selected to restore and ultimately reduce those total effluent amounts leaving Richmond. What if there was an easier way to achieve the Land Cover changes proposed above simply by expanding the extent of the focal area? That is what we undertook next: a correlated iTree Hydro analysis of the entire City of Richmond's watershed. From a logistical, regulation, and policy perspective, enacting Land Cover change on a scale of this size enables Richmond to have a significantly higher chance of success and the project alternative to have a greater chance of implementation in the first place (Strayer et al. 2003). This is due to a good portion of the watershed of Reedy Creek being occupied by Midlothian Turnpike and the heavy development surrounding it. As construction and improvements have just been performed on Midlothian Turnpike in the area, it is extremely unlikely that the City of Richmond would be willing to reverse some of this land cover from Developed to Shrub. The Reedy Creek watershed, only 11.42 km^2 in size, is dominated by the Midlothian Turnpike and adjacent development and suburbia – the Developed/Impermeable area makes up 84% of the watershed. Developed lands of this kind are extremely built up against Land Cover change towards shrub-type Land Cover. Therefore, it would be next to impossible to successfully implement a ten percent change on the immediate area of Reedy Creek – changing developed land to shrub land is significantly easier over a larger focus area and over varied, less intensely developed Land Cover types.

This spatial statistical analysis recommends the adoption of a broader extent of focus to achieve pollution reduction goals. As an alternative to the risky Reedy Creek stream restoration, spatial statistical analysis recommends a Land Cover change of 10% of the current developed area to shrub. Moving towards a higher permeability in the City of Richmond's watershed via the removal of impermeable surfaces (developed land) and substitution with highly permeable Shrub Land Cover will result in a reduction of Total Suspended Sediment (TSS), Total Nitrogen (TN), and Total Phosphorus (TP) loads that reach the Chesapeake Bay. Enacting the ten percent Developed to Shrub Land Cover change over the larger-scale City of Richmond rather than smaller-scale Reedy Creek watershed will ensure a higher chance of this alternative plan's success.

Section IV: An Ethical Analysis of the Reedy Creek Restoration Project

Christie Marsh

Introduction

The Intergovernmental Panel on Climate Change (IPCC 2014: 1) defines vulnerability as, "The extent to which a natural or social system is susceptible to sustaining damage from climate change." Vulnerability is a function of both the physical system's sensitivity to changes in climate and the ability of the societal system to adapt to said changes. Recently, several organizations have formed to produce assessments that define regional vulnerabilities to environmental issues for the sake of informing adaptation policies. With the increasing threat of a changing climate, adaptation policies are both a necessary and urgent response for successful adaptation (Adger 2009). The majority of these policies focus on technological, financial and institutional barriers that limit adaptation to government policies. Yet, in the absence of these barriers, local communities may still struggle to adapt to policies. As a result, the adaptive capacities of local communities to state environmental initiatives may be misjudged. This analysis seeks to address this issue by **(1)** identifying if a community's values cause a disconnect between government adaptation policies and the local community and **(2)** using a case study of the Reedy Creek Coalition to convey why a community's values should be considered in environmental analyses incorporating adaptive capacities.

Methodology

I began my research by compiling and analyzing various literatures focused on a society's adaptive capacity to climate change. My focus was to determine whether ethical factors were considered in these climate change adaptation reports. Sources included books depicting the role that ethical factors that are endogenous in society have on limiting adaptation to cities' climate change adaptation reports detailing scientific variables constraining adaptation, as well (see Figure 14). I selected four models currently utilized to determine a society's ability to adapt to state environmental initiatives (Figure 14). I chose these models with 3 different factors in mind: (1) what is the probability that it will be used as a basis for future reports? (2) what is currently our best available vulnerability assessment? And (3) what do current reports that consider internal barriers inhibiting a society's adaptive capacity determine as these barriers?

The challenge of climate change will force government to create policies to encourage citizens to adapt to a changing environment. Local communities will respond to these environmental policies and constraints in a variety of ways. In this study, I focus on the Reedy Creek community to determine how well they adapt to a city's proposed stream restoration. I conducted three key informant interviews within the Reedy Creek Coalition (RCC) and Forest Hill neighborhood and also derived information from an eleven-person RCC meeting that discussed the RCC's perspective on city stream restoration policies. I then analyzed these comments to determine the values of the community.

Prior Models' Depictions of Social Vulnerability

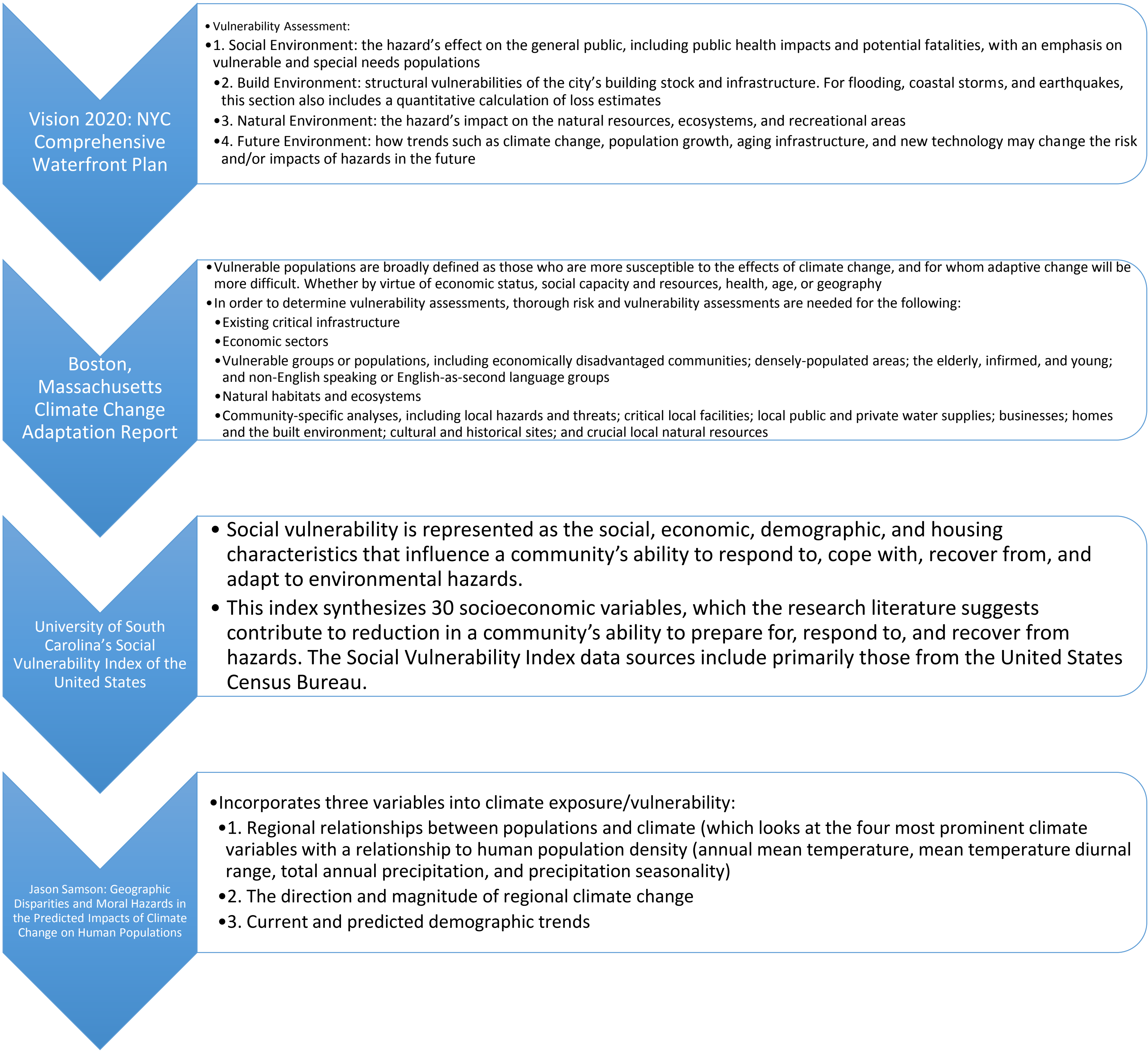

Figure 14: Adaptation Model. Created by Christie Marsh.

Figure 14 above depicts four conceptual frameworks of global indices that are used to calculate human vulnerability to adaptation initiatives. I chose these frameworks to represent three criteria: (1) the probability that the frameworks will be used as a basis for future reports, (2) to depict our current best available vulnerability assessment, and (3) to depict the internal barriers limiting a local community's adaptive capacity that are currently being considered for future reports.

The *Vision 2020: New York City Comprehensive Waterfront Plan* intends to identify and pursue strategies to increase the overall city's resilience to climate change and sea level rise. Crafted with the help of the city, state, and federal agencies as well as non-governmental advisory groups and members of the general public, this plan offers vulnerability-assessment suggestions that will be used as a guide in the future for public and private sectors alike when addressing vulnerabilities (Margolies 2014). Likewise, the Boston, Massachusetts Climate Change Adaptation Report will be used by other agencies to evaluate potential adaptive strategies' feasibility (Cash 2011: i). In this report, vulnerability assessments determine levels of susceptibility and exposure to and impacts of climate change among people, physical structures and assets, natural resources and the environment, economic conditions and other resources and interests. In this report, adaptive capacity varies by type, scale, scope and institutional responsibility (Cash 2011: 3).

The University of South Carolina's Social Vulnerability Index (SoVI) of the United States measures the social vulnerability of U.S. counties to environmental hazards through a comparative metric that facilitates the examination of the differences in social vulnerability among counties based on 30 socioeconomic variables (SoVI Frequently Asked Questions 2013). The Social Vulnerability Index facilitates local, state, and federal government efforts to improve emergency preparedness, planning and response and disaster resilience. Both policymakers and practitioners utilize the SoVI to determine the adaptive capacity of a county (SoVI Frequently

Asked Questions 2013). The fourth framework considers a spatially explicit approach for predicting the impacts of climate change on human populations. It combines climate change forecasts with current relationships between human density and climate and contrasts predicted vulnerabilities with demographic growth rates to create a climate-demography vulnerability index (Samson et al. 2011).

Understanding Human Values

Variable was not identified	Vision 2020: NYC Comprehensive Waterfront Plan	Boston, Massachusetts Climate Change Adaptation Report	University of South Carolina's Social Vulnerability Index of the United States	Jason Samson: Geographic Disparities and Moral Hazards in the Predicted Impacts of Climate Change on Human Populations
Values				

Figure 15: Values in Adaptation Reports. Created by Christie Marsh.

After investigating the four conceptual frameworks used to calculate vulnerability to climate change, I realized that modern indices that attempt to define the limits to adaptation to environmental initiatives emphasize scientific barriers as constraints. Yet, in addition to these aforementioned barriers to adaptation, internal factors, such as cultural values, are limiting the adaptive ability of a society. In turn, the adaptive capacities of societies are being overestimated.

In Figure 15 above, I examined the four conceptual frameworks and determined that these reports overlook the role that value systems have on the adaptive capacity of local communities to environmental initiatives.

A system of values specifies, "Permissions, norms, duties, and obligations; it assigns blame, praise, and responsibility; and it provides an account of what is valuable and what is not" (Jamieson 1992: 147). Embedded within values lies cultural content shaped by constraints and opportunities of a society. For some individuals, communities and cultures, the agricultural landscape provides a sense of stability, historical connection, identity and a sense of belonging, and climate change's alternation of this landscape may result in irreversible loss to these people (Adger et al. 2009: 172). Consequently, people may be less willing to adapt to changes in their environment because they may value traditional sectors and livelihoods and seek to preserve cultural icons and identities deeply held in their landscapes.

Discussion

The research indicated singularity in thought between the four models. The models focused on adaptive strategies that are scientifically, technologically and institutionally based instead of considering a more pluralistic and integral approach. The four reports neglected to fully consider the value systems that are latent and inherent within a society. The analysis here acknowledges the diverse role of values in global change processes and does not regard them as epiphenomenal. In contrast to systems and behaviors that can be objectively measured and observed, values subjectively influence the government adaptation measures that are considered desirable and thus prioritized (Adger et al. 2009). This suggests a lack of consideration of moral philosophy in adaptation initiatives.

Currently, ethical factors, which are concerned with how we ought to live and how humans should relate to each other and to the rest of nature (Jamieson 1992), are largely overlooked in the current models depicting social vulnerability to climate change. Yet, since global scale analyses of adaptation pathways cannot easily capture the diversity and often-conflicting nature of internal adaptive barriers within a society, such as cultural values and the loss of identity that people value, this results in the overestimation or underestimation of the adaptive capacity of a community. Hence, in order to successfully determine those populations most vulnerable to climate change, current adaptation analyses must consider the values in a local community. This will allow for modelers to determine who will have more difficulty adapting to climate change and to alter their subsequent policies accordingly.

Case Study: Reedy Creek

In order to gain a better understanding of a community's adaptive capacity, I empirically tested my model with Reedy Creek, where, in the absence of external barriers, internal factors might inhibit the society's adaptive capacity. In order to test this, I met with members of the RCC and asked them various questions to gauge the community's adaptive ability to a state environmental initiative.

Reedy Creek was one of five streams the City of Richmond planned to restore in order to meet the EPA's pollution reduction goals; however, the proposed restoration project generated significant and unpredicted opposition from the local residents. For the members of the coalition, their culture and landscape hold a value for them and provides them with a historical connection and identity. Crooked Branch Ravine Park, one site within the proposed project area, holds immense passive recreational value and bequest value for the RCC community (Taylor Holden, personal interview, 2017). Multiple generations of residents have used and valued the riverine landscape over the last 100 years. This long historical relationship details the emotional attachment and dependability that people have on the area (Dr. Amy Treonis, personal interview, 2017). Such internal societal values act as barriers to adapting to the state's proposed environmental remediation, and potentially to "natural" landscape alterations associated with climate change.

The RCC is a volunteer organization that prides itself in its commitment to restoring the health and beauty of Reedy Creek, exemplified through their mission statement, "Stop the Stream Restoration!" (RCC 2016b). The organization is comprised of community members ranging from scientists to lawyers to retired citizens who are passionate about maintaining the health and aesthetics of their neighborhood. A driving factor for the opposition of the proposed restoration project is the historical ties that many of the lifetime Forest Hill residents have in Reedy Creek. Crooked Branch Ravine Park, located within the project area, has immense passive recreational value as well as bequest value for the community. Unlike most of Richmond, this park is undeveloped and provides a unique and relatively untrammeled green space. The residents' passion for their park and creek is largely responsible for the sustenance of the coalition (Taylor Holden, personal interview, 2017). Moreover, this connection between the community and the landscape is inhibiting their ability to adapt to change, as the landscape provides a value to them that emphasizes the preservation of culture and identity.

The unique historical roots the community places on the landscape convey their dependability on the climate constraining their adaptive ability. In other words, the citizens favor the natural conditions of the creek and altering its pristine nature will negatively affect their relationship with the landscape (Samson et al. 2011: 1). Moreover, the citizens currently use the stream and the park and older members of the community used the stream when they were children. This long historical relationship details the emotional attachment and dependability that people have on the area (Dr. Amy Treonis, personal interview, 2017).

One member of the coalition, Dr. Amy Treonis, an associate professor of biology at the University of Richmond, believes the community is particularly sensitive because the City of Richmond does not have a good record of maintenance on other projects. This, in turn, negatively affects the community's perception of the city and heightens their perception of the risks associated with the city's environmental initiatives (Dr. Amy Treonis, personal interview, 2017). Successful stream restoration projects require a high level of maintenance and surveillance; yet, the City of Richmond does not have a good maintenance history of environmental projects, such as the dredging that occurred in Forest Hill Lake and the restructuring and stabilizing of stream banks on Albro Creek (RCC 2016b). As a result, RCC has a higher perception of risk and is thus even more unwilling to adapt, further affecting their vulnerability.

Looking Ahead

By studying the effectiveness of government interventions where vulnerabilities are persistent and entrenched in deeply held values, I determined that it is impossible to characterize the values of the global population in *one* analysis. This is because a global scale analysis of adaptation pathways cannot capture the diversity of regional and local values. As one member of the RCC stated, "It was a very superficial theater of involvement. There was no attempt at getting any community reaction whatsoever" (Reedy Creek Coalition member, personal communication, 2017).

Nonetheless, future reports such as Vision 2020: NYC Comprehensive Waterfront Plan and Boston, Massachusetts Climate Change Adaptation Report plan to utilize one analysis to determine an entire society's adaptive capacity. This will produce results, as exemplified through Reedy Creek, contrary to those originally anticipated: some locations will successfully adapt while others will not, owing in part to a difference in cultural values. Consequently, we must instead implement adaptation measures on a localized scale. Decision-makers remote from the realities of the localized cultures, such as Reedy Creek, should place a stronger emphasis on decentralization and local stakeholder participation. Full community involvement in adaptation procedures and policies is beneficial because the local community is the best source of determining how climate change will affect their local environment because they know their capacities and their landscapes. "Individuals and communities will respond to the prospect of change differently when the local knowledge in decision-making is no longer invisible" (Adger et al. 2009).

Conclusion

Effective models for calculating social vulnerability to climate change are typically limited to scientific understanding and neglect the importance of intercommunity dynamics constraining adaptation. This may result in current environmental development policies acting as obstacles to both mitigation and adaptation strategies instead of leading to social progression. Ethical elements inherent in any society, such as values, restrain the successful adaptive response of a society and thus must be considered when developing a report outlining such limiting factors (Jamieson 1992). By ignoring ethical factors, the adaptive capacity of communities such as Reedy Creek may be misjudged. Hence, the role of ethics and its manifestation in the current models for calculating social vulnerability is critical and characterizes the ability of a society to adapt to government mandates or climate change more broadly.

Conclusion and Acknowledgements

The Reedy Creek restoration project was extremely controversial from the beginning. Numerous stakeholders influenced the project, from government agencies to stream restoration experts and neighborhood coalitions. Though stream restorations can adequately contribute to pollution reductions mandated by the Clean Water Act and the United States Environmental Protection Agency, it is this group's conclusion that the Reedy Creek stream restoration has more risks than benefits. This conclusion is based on the available studies from the project's stakeholders and independently-conducted GIS analyses, and perhaps further studies could further the dialogue on this controversial project.

This restoration project is an excellent case study for how the City of Richmond approaches environmental management more generally. Though periods for public comment were made available, relevant documentation indicates that most decisions were made solely by city officials without incorporating public opinion. The Planning Commission and City Council meetings therefore served as one of the best spaces for public engagement, and the Reedy Creek Coalition took full advantage of this opportunity to vocalize their concerns. Though the city may have anticipated widespread support from the community, it is because of the coalition's dedication, drive, and passion for their landscape that the restoration has faced such significant opposition.

We would like to send a special thank you to all those who helped us in our research endeavors: Bill Shanabruch and the Reedy Creek Coalition for providing tours, volunteer opportunities, pages of documents to sort through, and excellent feedback; Dr. Amy Treonis, Taylor Holden, and Bryan Figura for their time and thoughts on the restoration project, and Dr. David Salisbury, our professor, for all of his guidance and feedback.

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