Minimizing Stormwater Runoff Pollution in Seattle using Green Infrastructure

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Abstract

Project Statement

Stormwater runoff is a major source of pollution in the Puget Sound region. Runoff accumulated from the streets mainly is produced by vehicle pollution and other waste produced by humans. With the Seattle region known to have a rainy climate, traces of oil, fertilizers and pesticides, soaps, bacteria, and more are washed directly into nearby rivers, streams, lakes. This is critical when the municipality is nearby the Puget Sound, creating environmental issues like endangering species like forage fish, salmons and orcas.

Project Purpose

Our project brings awareness to places in this metropolitan that are lacking support in integrating green infrastructure to it's landscape. We believe that land use on the streets that vehicles past by can be renovated by building with nature. More developed neighborhoods in Seattle have seen great efforts to improve their environmental foot print by this easy and natural solution, but it would be great to see less funded areas have the same growth too. Biodiversity, better air and water quality and less urban runoff can be improved as a collective city as we begin to pinpoint which areas are in need to fill the environmental gap in this municipality.

Results/Accomplishments

Through compiling our geodatabases with multiple feature classes from many sources, we were able to compile a comprehensive idea of Seattle's current use of green infrastructure. The use of rain gardens, bioretention swales, and permeable sidewalks seems to already prevalent in most places, but our study is focused on areas that can use these environmental networks to try to replicate the green results.

In the end, we saw that green infrastructure was mainly absent in the south end of Seattle, particularly in the Industrial District. We viewed this as a critical at risk area because it fit one of our assessments of being near a body of water, albeit being the Duwamish Waterway that sources from Green River and flows into the Puget Sound. We saw that high density of green infrastructure development was regularly in residential areas, but in places with high vehicle traffic volume it seems harder to implement which is critical places where it's most needed. We compromised the idea of proposing possible permeable pavement to filter the water entering streams and basins.

Possible Stakeholders

This rich amount of information we gathered can be useful to various groups such as city planners, government officials, other scholars/researchers and possibly ordinary citizens of Seattle. This could increase the importance of green infrastructure to be funded in city budget for development projects. Especially with how the municipality of Seattle has been growing exponentially, we want to show the public that we are a green first class city by further proposing implementation to less attentive areas.

We create new knowledge through this research project since we gathered multiple sources of information through feature datasets and classes to answer our research question. Our goal is to endorse the effectiveness and naturality of green infrastructure and to encourage future researchers to take our project to greater heights. With our limited time constraints we did what we can do, but there's still a lot of room for stakeholders to use this knowledge to built on top of we provided in this project.

Introduction

The purpose of this project is to identify which areas of Seattle are most vulnerable to pollution caused by stormwater runoff, and subsequently determine which areas can benefit the most from implementing green infrastructure methods (permeable pavements, bioretention swale, green streets etc.) to mitigate such pollution.

Urban areas generate large volumes of stormwater runoff susceptible to contamination by pollutants, which can have damaging effects to lakes and streams as they are moved away from cities (Copeland, 2016). According to the Stormwater Management Research Program, Puget Sound wetlands used for stormwater treatment are subject to deterioration of its aquatic ecosystem over time (Anonymous, 2000). The rapid growth of urbanization has played a large part in the degradation of ecological health of watersheds in the Puget Sound, and the implementation of green technologies in the urban landscape is urged in order to mitigate the root cause of stormwater runoff pollution (Morley & Karr, 2002).

Therefore, it is important that we minimize the damage that is caused to our waterways as it can affect many businesses, transportation, and individuals that depend on clean aquatic ecosystems. Green infrastructure is suggested as the most viable method because of how sustainable it is in the long term (N/A, 2009). There have been examples of green infrastructure planning focused on Seattle, which utilized a geodesign-based approach to determine how to strategically implement green infrastructure in an urban landscape (Roderick, 2017).

We believe that our geodatabase can be utilized as a tool for strategic planning as well, since our aim is to create a well-informed database based on data regarding existing green infrastructure in the city, as well as drainage systems and networks of streams, all of which can be used to generate maps to visualize this information and effectively showcase which areas of Seattle require the most attention for green infrastructure implementation.

This has led us to the following research question:

Where in the City of Seattle should green infrastructure-based street stormwater runoff management (permeable pavements, bioretention swale, etc.) be focused to most effectively minimize the amount of pollution running into the Puget Sound based on site drainage area (SDA) assessments?

The results from this report could benefit various stakeholders. One stakeholder can be city planners, as this information will be useful for them in determining which areas should be considered from green infrastructure development. Scholars studying a similar issue may also benefit from the results of this project, as our findings could be a useful resource for them to refer to when developing their research.

This report will first discuss the methodology used for this project, followed by the results of our findings, then discuss the conclusion of the project and end with any recommendations we have for those interested in carrying out a similar study.

Project Method

Acquiring the Data

Our data was retrieved from government owned GIS databases, specifically those which specialized in information about King County and the city of Seattle. This includes King County Geographic Information System (KCGIS) managed by King County GIS Center, which provides GIS data about King County. Another source is Seattle GeoData managed by the City of Seattle, which provides free access to GIS data that is generated by the city.

More information about each feature and its feature dataset can be found in the “List of Feature Datasets and Feature Classes” table in the appendices.

<u>Developing the Geodatabase</u>

Creating the geodatabase was not a linear process as we first expected, as there were constant changes made to improve the way the data was presented and organized.

Initially, we referred back to our research to identify what issues needed to be addressed in our geodatabase and took this into consideration when brainstorming what potential feature datasets and feature classes to create.

After deciding what features to include, we referred to the previously mentioned government-owned GIS databases and attempted to look for the desired features. From there, we were given one of two options: the first is that we found the feature that we wanted, ready to be used as it is, and the second was that we found a feature that required some manipulation in order for it to suit our purposes. In the latter case, most of the manipulation involved clipping data that covered the entire King County region so it only covered the city of Seattle.

Figure.1 Flowchart showing the overview of steps taken in creating the geodatabase.

For instance, the Roads_Seattle class was created by clipping a feature class called Roads_King taken from KCGIS using a polygon feature class called *Seattle_Polygon* (represents the total land coverage of Seattle). This polygon was something that we had to create ourselves, as we could not find an existing polygon with the same criteria in any of the sources that we used. The polygon was made by importing the line feature class *Seattle_City_Limits* (showing the Seattle city limits taken from Seattle GeoData onto a basemap, then tracing the coastline and converting the line features to a polygon.

After making sure the features imported to the database fit our criteria, we edited the metadata as required. In most cases, the metadata had to be edited as the entries were incomplete when we first obtained the data. We had to refer back to the source of the data in order to gather the appropriate information to be added to the feature metadata. The description was paraphrased from the descriptions listed in the source that we obtained each feature class from.

As we developed our geodatabase, there were a few changes that we had to make in order to ensure that the data in our database was necessary and relevant in relation to our research question. We initially had a feature dataset showing sewage systems but we decided that it was not very relevant in regards to stormwater runoff pollution problems for our purposes. Additionally, existing green infrastructure feature classes, we had to create an additional feature dataset called *ExistingInfrastructure* in order to accommodate this.

Software used

ArcCatalog was used to develop the database, specifically for importing the various feature classes, creating feature datasets and editing the metadata. ArcMap was used for creating the *Seattle_Polygon* feature, for which the details of its creation is mentioned previously.

As this project was a collaborative effort, we used a variety of online services to ensure thorough communication and access to synchronized information. Communication between team members was carried out on a Slack server, and Google Docs and Slides were used to develop documents and presentations. The database creation process flowchart was made using an online service called SmartDraw, and the flowchart diagram created there was converted to a jpeg to be used in this report.

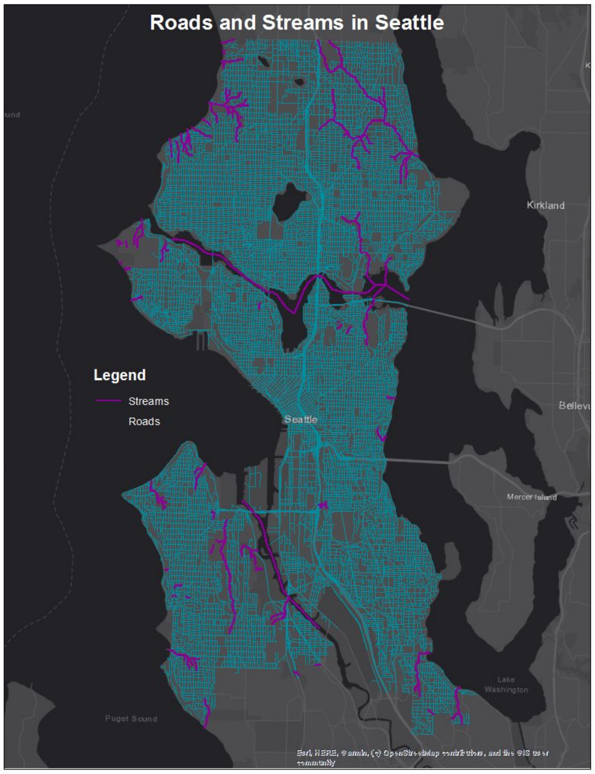
Major Challenges

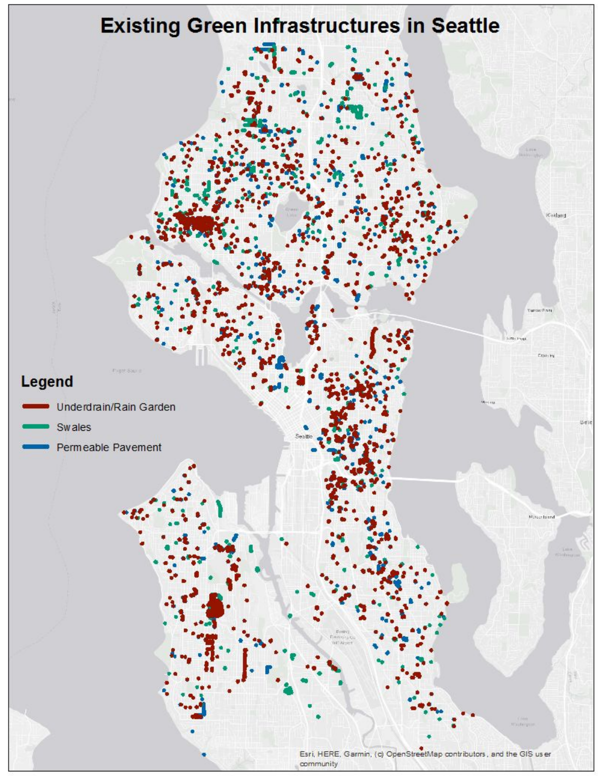
One big challenge we faced was acquiring relevant information from government GIS sources. There were many times where the information had to be manipulated to fit our criteria, and that was not a simple process. Initially we did not even have a *Seattle_Polygon* feature as we had assumed that the *Seattle_City_Limits* feature would suffice for the clipping process. It was not until after we clipped multiple feature classes that we realized that we actually had to clip the data using a polygon in order to achieve the desired results.

Findings

Results

Our geodatabase ended up including five feature datasets, *HydroNetwork, Landuse, RoadNetwork, ExistingInfrastructure* and *Drainage*. Feature classes were grouped into these four datasets according to which one they fit the most and the topological relationships between classes. *HydroNetwork* and *Landuse* ended up only having one feature class each that was actually of use to the project, but organizing them into the feature datasets allows for future expansion of those feature datasets if we find more data that is useful to the project and have some sort of relationship by data or topological relationship. We were able to find feature classes of a few types of green infrastructures that have already been built around Seattle, which is useful because an analysis of what areas need green infrastructure the most should try to exclude areas that already have it built. Our preliminary analysis involved examining all of the data that we had and making an assessment based on the following three factors: the presence of green infrastructure in a particular location, proximity to a body of water like a river, stream, lake, or the Puget Sound, and the drainage conditions (basin, outfalls).





Examining the two maps above, the most major absence of green infrastructure is in the southern half, in the industrial district. It could be that stormwater runoff is the least of our environmental concerns in that area, and there certainly seem to be less streets in the area, but it would be worth investigating the current pollution levels in the stormwater runoff in the area, to mitigate as much of the pollution in the area that we can given its proximity to both the Duwamish River and the Puget Sound itself. It would be extremely difficult to implement green infrastructure solutions in the Belltown and downtown areas, but if possible, the density of cars in the area would warrant investigating the possibility of putting down permeable pavement in the area to help filter the water. Those are what appear to be priority areas. Ballard and the general northwestern part of Seattle seems to be doing the best with green infrastructure, as it has the highest concentration of all three types of infrastructures that we included in our database.

Discussion of Results

Our data and findings would be useful to city planners who are discussing drainage and infrastructure issues. Our data would most likely already be available to such people but the organization that we have done can be a good starting point for their more comprehensive projects, which will usually include much more data than what we have gathered here, on a good many more subjects. They can also build on what we've done in order to get a more detailed and definitive answer. Our results are not absolute, as we do not have prior experience in this kind of work, but we believe that they can be a good starting point for people to build on. One regret is that our results are not as accessible as we would like, as the feature web services are not very stable and seems to display less than half or even a quarter of the time.

The results are mostly what we already expected. Dense urban and industrial areas tend not to focus on green infrastructure improvements, while residential areas are always open to improvements, especially with things like bioretention swales and rain gardens that improve the scenery of the neighborhoods. We were, however, expecting to see less existing green infrastructure but were pleasantly surprised. We expected Seattle, as an urban area, to be somewhat inflexible in integrating these sorts of things, but it seems that that assumption only holds true for the densest areas and industrial area. The areas that more closely resemble suburban areas have integrated green infrastructure relatively heavily, and although there is more that can be done, they have done a good job in mitigating pollution from stormwater runoff.

Conclusions

The feature datasets and feature classes we complied in our geodatabase did pinpoint every aspect we mentioned in our research question. We addressed possible green infrastructure efforts by custom feature dataset we called "Existing Infrastructure" that contained Seattle geodata about where existing green infrastructure was located such as underdrains/rain gardens, permeable pavement, and swales. We determined where the accumulated pollution could flow, eventually into the Puget Sound through the Drainage and HydroNetwork datasets that contained data about Seattle's basins, watersheds, and streams that some way or another end up into a major body of water, like the Puget Sound.

Finally, we determined possible area sources of stormwater runoff by looking at the Seattle road network and drainage outfalls from the RoadNetwork and Drainage feature datasets, respectively. Another set of data that could have been suitable to our geodatabase is something that can assess the landscape vulnerability or resilience of an area, particularly to pollution and stormwater runoff. Similar to the Coastal Vulnerability Index, this could have been useful to evaluate which areas can handle or resist pollutants well, with or without green infrastructure.

Recommendations

Our recommendations to others that might want to explore a project like this in similar magnitude, is to initially be specific as possible for what needs to be accomplished. Especially when it comes to the problem statement and research question, we should have a comprehensive idea of what exactly we want to accomplish out of the data we gather. We had a serious complications when we figured that some of the information we needed to answer our question wasn't available anywhere. So having a more substantive research question is the way to go.

Also, we initially just compiled a bunch of feature datasets and classes that might be fitting to our problem statement. But, looking and analyzing the data first would have been nice to see what we have and what we actually needed. The saved time we could had have, could have went to finding more specific and complex data that could further answer our question in detail. Our project has a lot of room to grow and that is needed in the next steps of further finding other data that could clarity to our answer.

References

Anonymous. 2000. "The Impact of Stormwater on Puget Sound Wetlands." *Watershed Protection Techniques*, 3 (2): 1-6. Ellicott City. https://search-proquest-com.offcampus.lib.washington.edu/docview/196827586/fulltext/37B0713DD8412EPQ/1?accountid=14784.

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Appendices

URLs to Feature Map Services

http://geog-gs01.geog.uw.edu:6080/arcgis/rest/services/GEOG482/imabr777_g482_roadsandstreams/FeatureServer http://geog-gs01.geog.uw.edu:6080/arcgis/rest/services/GEOG482/imabr777_g482_existing/FeatureServer

List of Feature Datasets and Feature Classes

Feature Dataset	Feature Class Name	Description	Data source
Drainage	Seattle_basins	Areas that drain to a receiving water body via outfall(s) in the formal or piped infrastructure.	Seattle GeoData
	WRIA_Seattle_Watersheds	Polygon feature class showing the water resource inventory areas clipped to Seattle area	WA Department of Ecology - Research and Data GIS
	SeattleOutfall2010	City owned drainage outfalls, storm water only. 2010	City of Seattle
Landuse	Parcel_Seattle	Shows tax parcels within the city of Seattle.	Made by clipping Seattle_Polygon from Parcel_King (General representation of tax parcels in King County and describes land use, taken from KCGIS)
	Seattle_Polygon	Represents the total land coverage of the city of Seattle.	Made by tracing coastline and Seattle_City_Limits (A line feature class showing the Seattle city limits taken from Seattle

			GeoData) from a basemap, then turning line features to polygon.
RoadNetwork	Roads_Seattle	Parcel based streets of Seattle derived from cadastral database.	Made by clipping Seattle_Polygon from Roads_King (Parcel based streets of King County derived from cadastral database, taken from KCGIS).
HydroNetwork	Streams_Seattle	Contains water courses for Seattle drainage basins.	Made by clipping Seattle_Polygon from Streams_King (Water courses for King County drainage basins including some areas in adjoining counties, taken from KCGIS)
ExistingInfrastructure	Underdrain_and_Rain_Garden	Underdrain piping systems are provided to prevent prolonged ponding of stormwater or to collect and convey water to another facility. Rain gardens are less engineered systems that are designed to mitigate water from the sidewalk only and have two inches or less of ponded depth.	Seattle GeoData
	Permeable_Pavement	Permeable pavement is a paving system	Seattle GeoData

		which allows rainfall to percolate into an underlying soil or aggregate storage reservoir.	
	Swales_Seattle	A polygon feature class showing DWW Swales. Swales are generally shallow depressions with a designed mix of soil and plants which break down pollutants through natural processes while reducing runoff.	Seattle GeoData