The Impact of Urbanization on Streamflow in the Puget Lowland Region

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Question

How does urbanization affect streamflow in three different basins with differing degrees of urban development in the Puget Sound region?

Abstract

This study is about the effect of urbanization on streamflow, specifically in the Pacific Northwest, and how different degrees of urbanization produces different flow rates. This was a synthesis project, finding gauge data about the basins and analyzing it. Two basins were chosen from King County and one from Snohomish County based on their percent impervious surface and other characteristics such as size, shape, etc. Streamflow data from the past ten years was gathered for each basin and used to produce graphs. The data show that overall, the second most urban basin has higher flow rates but the most urban basin has the lowest flow rates. This is explained by the restoration work that the most urban basin has undergone to prevent further flooding. As urbanization continues to increase, the discharge rates in streams will also increase unless restoration work similar to what the most urban basin has had done is applied to other basins.

Introduction

As the human population continues to increase around the globe, so does the expansion of urban areas. This "expansion of urban areas" can simply be defined as urbanization or more specifically, "the conversion from rural land uses to residential and commercial uses" (Couch and Hamilton, 2002). As expansion increases, the amount of impervious surfaces also increases which leads to an excessive amount of water runoff during storms. The runoff from the streams then causes flooding. It's important to know that there are consequences involved with urban development and that these consequences are likely to increase as we change our approach to development. "Urbanization" is not a single condition; instead, it is a collection of actions that lead to recognizable landscape forms and, in turn, to changes in stream conditions (Konrad and Booth, 2005).

Some of the hydrological consequences of urban development include increased flooding and bank erosion, the redistribution of water from periods of baseflow to stormflow and physical disturbance of and changes to aquatic habitat (Walsh et al., 2005). Humans aren't the only ones affected, stream ecosystems are as well. To investigate these hydrological effects more closely, three basins with different degrees of urbanization were selected and analyzed. This study took place on the western side of Washington state, around the Puget Sound area. This region, west of the Cascades but east of the Olympics, is the coastal area of the Pacific Northwest and is commonly known for its wet climate. The three different drainage basins being analyzed are Tulalip Creek, May Creek, and Thornton creek, each having a different degree of urbanization. By exploring how the hydrology of these basins differ, there will be a clear picture of how the increase of urban development affects overall streamflow.

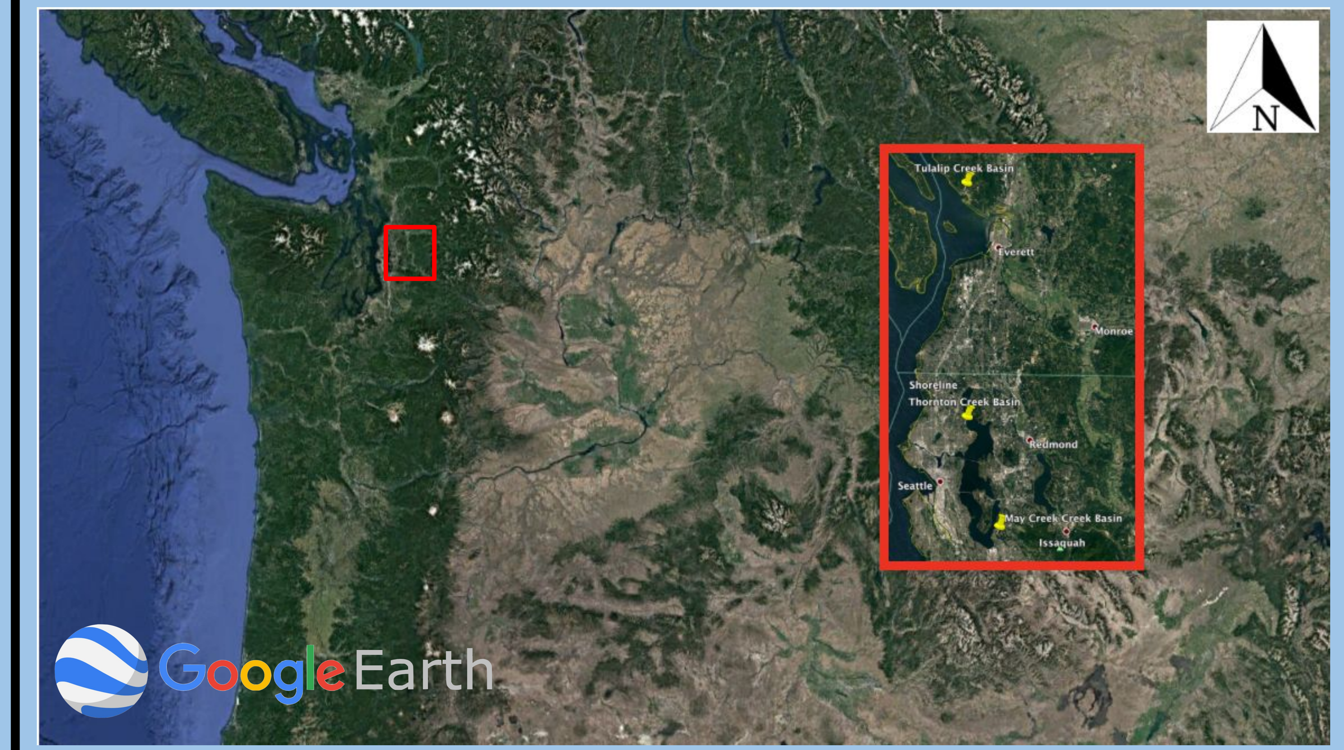

Figure 1: Map of the study area and locations of the basins. Small red square is study area in relation to Washington state, big red square is study area in relation to King and Snohomish counties. Yellow pins show the drainage points in each basin).

Methods

Basin Characteristics

- ➢ Searched for variation in percent of impervious surface while making sure size, shape and slope were similar.
- ➢ Looked for three basins that had similar climates
- ➢ The Streamstats program was used in the basin selection process (StreamStats)
  - Gave the outline of the drainage area and a table of values describing the basin (see table 1).
  - Percent impervious surface
    - <10% is unurban
    - 10-20% is moderately urban
    - >10% is urban
  - Area
    - Searched for basins under 20 square miles
      - easier to see the impact of urbanization than it is with larger basins
      - variation in size is as small as possible (table 1)
  - Shape
    - Drainage point determined if it was long and skinny or short and fat (figures 2, 3 and 4)
    - Limits the effects on discharge from the watershed
  - Slope
    - Affects the rate of runoff which impacts discharge
      - Steeper slope = more discharge

Data Selection

- Daily streamflow data was chosen from the last 10 years (2010-2019)
  - Displays the gradual change of urbanization
- Daily streamflow data was downloaded from the USGS and King County databases
  - Data for Tulalip Creek was from USGS
  - Data for Thornton Creek and May Creek was gathered from the King County database

Characteristic	Tulalip Creek	May Creek	Thornton Creek
Gauge number	12158040	12119600	12128000
Drainage area	15.64 sq miles	13.22 sq miles	12.08 sq miles
Impervious surface	3.88%	15.64%	44.51%
Total stream length	12.43 miles	14.5 miles	5.66 miles
Tree canopy	71.87%	51.88%	24.85%
Mean basin slope	5.4%	13.8%	5.61%
Basin shape factor	26.66	43.14	7.42

Tabel 1: Characteristics for each basin laid out. Basin shape factor is dimensionless. It is the ratio of the length to the width of the basin. Color coded columns coordinated with the borders of the basin imagery. (Streamstats)

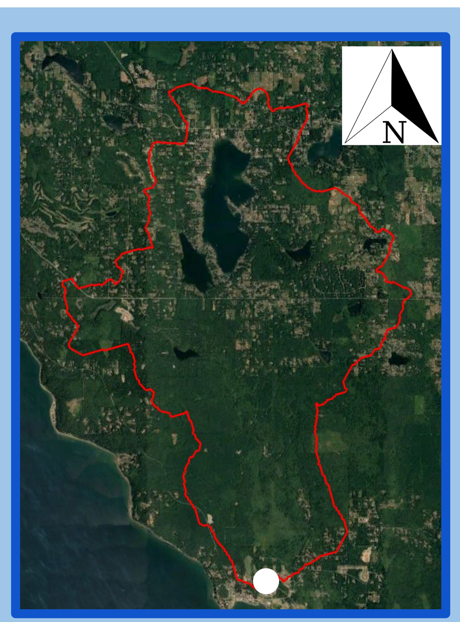

Figure 2: Tulalip Creek basin showing very little impervious surface due to amount of forestry (green areas) shown. White dot is displaying the point of drainage. (StreamStats) (Imagery from Google Earth)

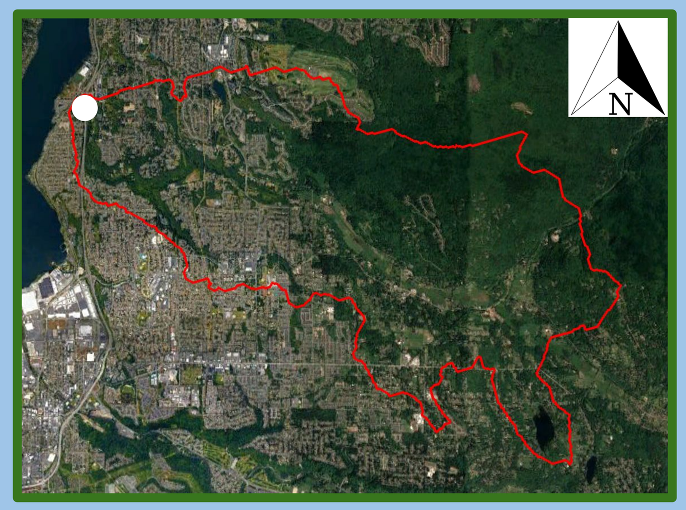

Figure 3: May Creek showing a moderate amount of impervious surfaces, left side mostly impervious, right side mostly forest. Point of drainage shown by white dot. (StreamStats) (Imagery from Google Earth)

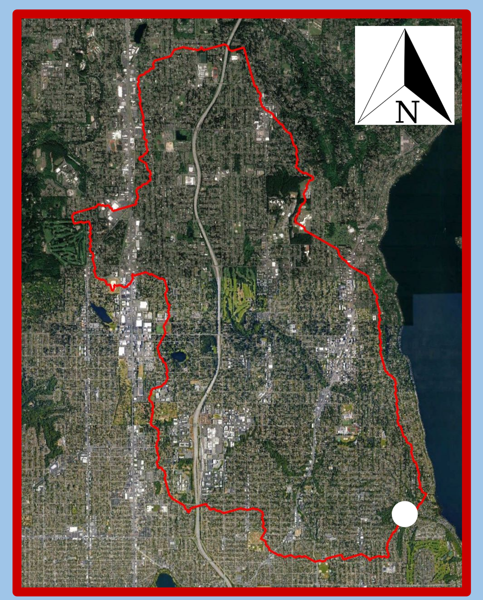

Figure 4: Thornton Creek basin showing a large amount of impervious surface shown by the grey areas. White dot displays the basin's point of drainage. (StreamStats) (Imagery from Google Earth)

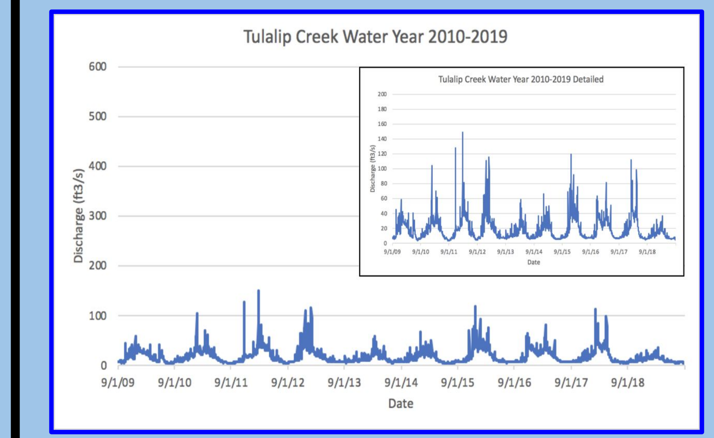

Figure 5: Hydrograph displaying the rate of discharge on a scale of 600 ft3/s as well as a scale of 200 ft3/s (to show more detail) during the span of nine years.

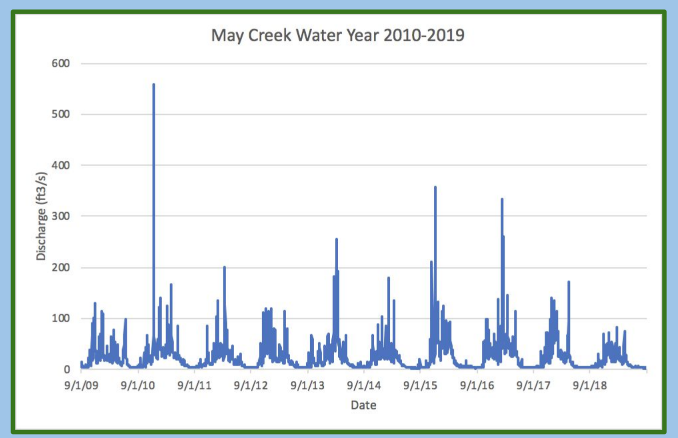

Figure 6: Hydrograph displaying the rate of discharge on a scale of 600 ft3/s during a nine year span.

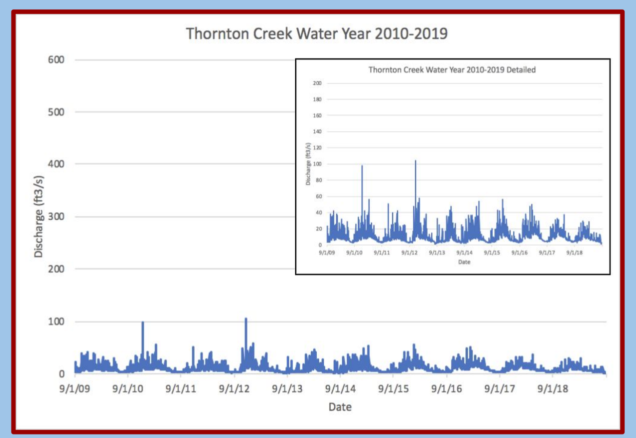

Figure 7: Hydrograph displaying the rate of discharge on a scale of 600 ft3/s as well as a scale of 200 ft3/s (to show more detail) during the span of nine years.

References

Couch, Carol, and Pixie Hamilton. *Effects of Urbanization on Stream Ecosystems*, 2002, pubs.usgs.gov/fs/fs04202/.

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Results

- There is an overall seasonal pattern shown in all three hydrographs
  - Increased flow during rainy seasons
  - Average flow November through April in ft3/s
    - Tulalip creek 28, May creek 49.3, Thornton creek 13.4
  - Average flow May through October in ft3/s
    - Tulalip creek 9.2, May creek 10.9, Thornton creek 7.1
- The 2016-2019 hydrograph for May Creek displays bigger and more frequent peaks than Tulalip Creek (see figures 8 and 9)

	Tulalip Creek	May Creek	Thornton Creek
Baseflow (ft3/s)	3.39	1.94	1.19
Peak discharge (ft3/s)	149	559.7	104
# of storms>150ft3/s	1	7	0

Table 2: Table displaying baseflow data, peak discharge data and amount of storms above 150 from all three of the 2010-2019 hydrographs. Data taken from hydrographs, all results in ft3/s.

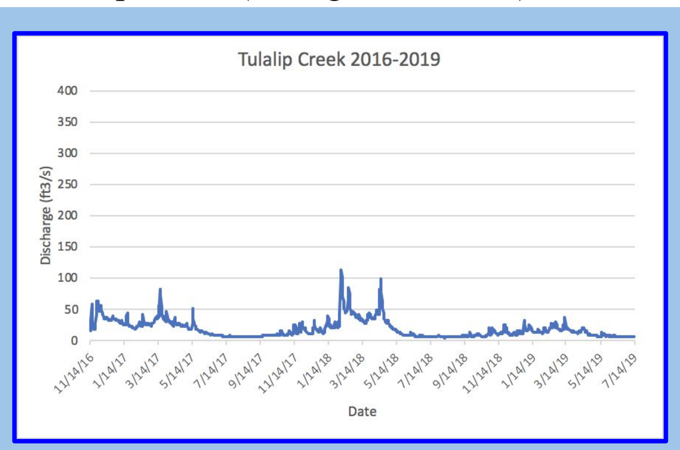

Figure 9: Detailed hydrograph for the least urban basin displaying a three year span to show clearer peaks and baseflows.

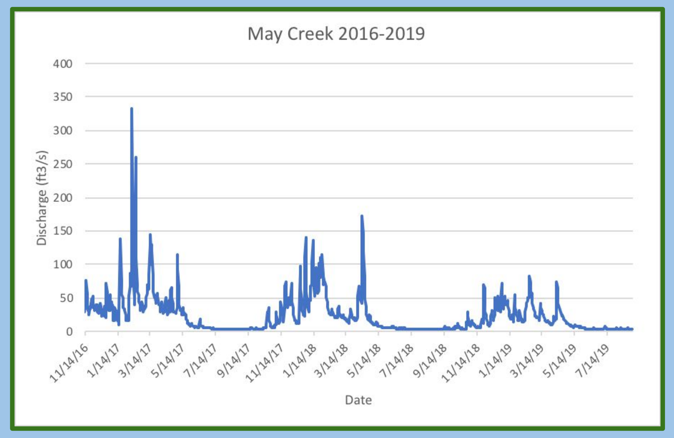

Figure 8: Detailed hydrograph for the second most urban basin displaying just a three year span to show clearer peaks and baseflows.

Discussion

- The data presented both show and don't show the impact of urbanization
  - May creek shows higher and more frequent peaks in its hydrograph which means it has a higher overall discharge rate than the other basins (figure 6)
  - Comparing the seasonal patterns for May and Tulalip Creeks, May creek has higher average flows for both rainy and dry seasons
    - Although Thornton creek is the most urban, it has the lowest average flows through both seasons
  - The urban basins have lower baseflows because they have reduced infiltration which means they have less groundwater being discharged as baseflow (Walsh, et al., 2005).
  - Thornton Creek's decade hydrograph has a lower discharge rate than both May and Tulalip Creeks even though it is the most urban
    - Shown by low peaks and low basflows (figure 7)
  - Comparing the 2016-2019 hydrographs, May creek is displaying more flashiness due to the steep rising limbs and higher peaks (figure 8)
    - Thornton Creek wasn't used in the comparison because of the restoration work done to it
    - Projects were designed to control flooding and erosion
    - Projects included funds to reduce combined sewer overflows and flooding; construct major stormwater detention facilities, new sewers, and storm drains (Hara, 2007)

Conclusion

To conclude, streamflow is drastically affected by the amount of urbanization. Basins that are in more populated areas, will have higher discharge rates with high peaks and low baseflows which is displayed by the May creek data and hydrographs. Thornton creek is more urban than May and Tulalip Creeks but it doesn't display those attributes. Although it is the most urban, it has had work done to it to manage stormwater and runoff. If this type of work could be applied to other basins, it would prevent flooding in many areas and improve the overall health and flow of streams.

Acknowledgments

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