Renton, Washington Stormwater Greenfrastructure Opportunity Assessment

STORMWATER GREENFRASTRUCTURE SITE PLACEMENT OPPORTUNITY REPRESENTATION FINAL REPORT

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Introduction

In partial fulfillment of the course requirements for Geography 582 GIS Data Management, the authors of this report have been charged with providing a geographic information system based representation of the existing site conditions and infrastructure related to stormwater conveyance and treatment in the City of Renton, Washington. Moreover, we were assigned to the task of using spatial and temporal data to develop an inventory of potential sites for protecting existing and / or developing new green stormwater infrastructure (greenfrastructure) in Renton. Our report is also our final class project. It provides the reader with the background, procedures, and resulting data that we combine to assist us in achieving our project's data representation and conclusions.

Our workflows are significantly influenced by the following definition and research question:

Definition. Greenfrastructure means green stormwater infrastructure. It refers to stormwater systems or practices that use or mimic natural processes to infiltrate, filter, reuse, or facilitate the evapotranspiration of stormwater on or off-site.

Research Question: Which datasets are needed to locate sites of opportunity for protecting existing and / or developing new stormwater "greenfrastructure" in Renton, Washington and what is an effective geoprocessing workflow that will help to discern those locations from the data?

Stormwater Management

Stormwater management is characterized by two competing anthropogenic design objectives that are diametrically opposed to one another (Krammer 2014):

1) In the interest of public safety and property protection, convey surface water away from properties, roadways, and structures as quickly as possible to prevent backwater flooding and subsequent impairment to structures or harm to persons during and immediately following extreme storm events.

2) In the interest of environmental protection and management, maintain, restore, or create storrmwater controls that help insure post development flow quantity, quality, and frequency will meet a predevelopment land cover type (e.g., historic condition) flows at specified storm recurrence interval design thresholds.

Problem. The crux of the issue that arises out of stormwater management objective 2 is that new development characterized by impervious surfaces dramatically changes the dynamics of runoff associated with rain storm events (Figure 1). Two significant differences between pre-construction and post-construction rainstorm events are:

1) The lag time between peak rainfall and peak runoff is reduced
2) The discharge flow at peak runoff is increased

In other words, the peak flow event occurs faster and carries more flow, thereby increasing in both frequency and intensity in areas occupied by humans and their structures. This means the associated landscape is subject to an increased risk of personal injury, loss of life, and property damage while transporting a wide range of pollutants into nearby surface waters.

In general, untreated urban stormwater runoff poses the following concerns:

1) Excessive sediment in stormwater can find its way into natural streams and fill in spaces between gravels in salmonid spawning beds, decreasing oxygen availability necessary for juvenile fry emergence and survival;

2) Excess nutrients runoff loads into streams can cause algae blooms. When the algae die off they are decomposed by bacteria in a process that removes oxygen from the water. Salmonids and other aquatic organisms can't exist in water with low dissolved oxygen levels (Mohamedali et al 2011);

3) Stormwater can intercept and carry industrial and household hazardous wastes like insecticides, pesticides, paint, solvents, used motor oil, and heavy metals toxic to aquatic life into streams and other aquatic areas;

4) Stormwater runoff from roads and highways can carry oil, grease, and heavy metals such as copper that can adversely affect migrating salmonid navigation and ability to avoid predation (Sandahl et al 2007);

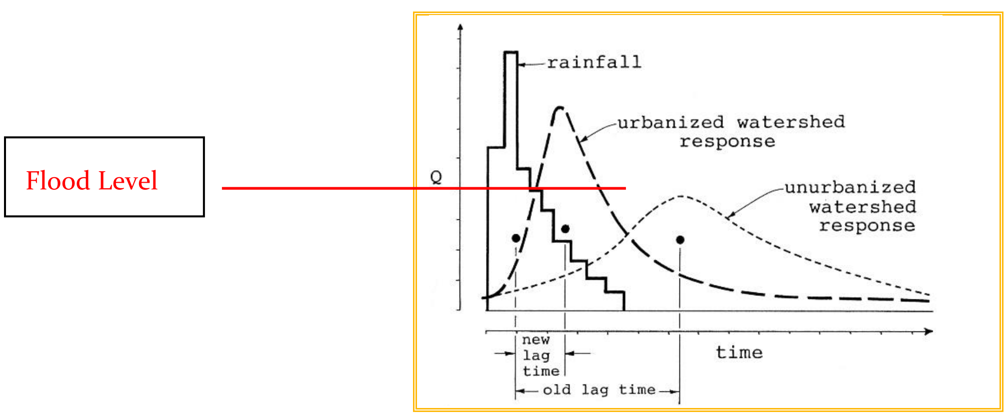


Figure 1. Comparison of Urbanized and Unurbanized Watershed Runoff Discharge Responses to Identical Rain Event.

5) Land animals and people can become sick or die from eating diseased fish and shellfish or ingesting water polluted by stormwater runoff; and

6) Flashy peak stormwater discharge (Q) can change the natural seasonal hydrographs of associated drainages to the extent of causing excessive channel degradations which over time accelerates the separation of streams from their floodplains and contributes to downstream bank erosion, flooding, and the consequent losses of property and human lives.

Solution. As environmental concerns related to stormwater began to reach actionable awareness by researchers, regulatory agencies, and advocates for environmental protection, new government and agency regulations and policies began to develop that stemmed from an overarching goal to maintain predevelopment hydrographs where new development occurred (Figure 2) aimed at alleviating, to the degree practicable, the adverse effects of stormwater runoff.

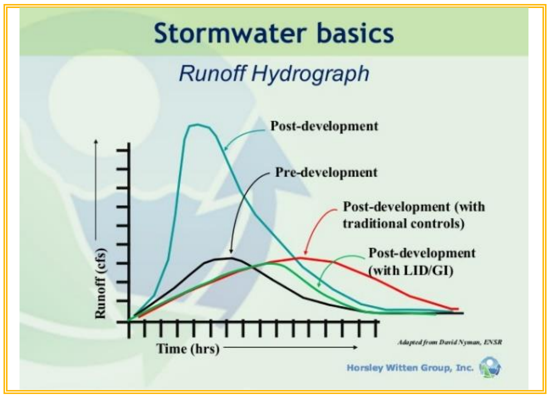


Figure 2. Comparison of Urbanized Watershed Runoff Discharge Responses to Different Stormwater Controls for the Same Rain Event.

During roughly the same time there was a growing recognition that relatively undisturbed natural features in the landscape such as wetlands and floodplains contribute to ecosystem services by intercepting stormwater moving through developed areas before discharging into adjacent surface waters (Collins et al 2010). In addition, there was increased research into finding ways to construct stormwater treatment controls that mimic the attributes of natural systems to achieve better stormwater treatment while serving a wider range of ecological benefits (Cammermayer et al 2000). It is primarily from the research findings of this kind of work that this report is based on the following four assumptions:

1) Preserving natural systems that inherently contribute to stormwater treatment reduces the need to build costly and hard engineered systems to replace their ecosystem services if they were lost to development (City of Mukilteo 2013);

2) For unavoidable losses, soft or bioengineered solutions can provide more effective stormwater treatment and generate a wider spectrum of ecosystem service benefits overall than hard engineered solutions (Wise 2008);

3) The City of Renton, Washington likely contains parcels of land that offer opportunities for the protection and augmentation of existing and / or newly developed green infrastructure for facilitating stormwater runoff treatment; and

Table 1a. Renton Stormwater File Geodatabase Datasets (vector).

Feature Dataset	Feature Class	Description	Source
Boundary	Renton	City of Renton boundary (Incorp-orated and Unincorporated)	http://www5.kingcounty.gov/gisdataportal/
Hydrology	Renton_ Basin	Surface water basins, sub-basins, and catchments.	University of Washington gishub database connection
Hydrology	Waterways	Rivers and streams in Renton drainage basin area.	http://www5.kingcounty.gov/gisdataportal/
Hydrology	100-year Floodplain	The geographic extent of the 100-year (1%) flood recurrence interval	http://www5.kingcounty.gov/gisdataportal/
Hydrology	Isohyets	Isolines of mean annual precipitation	http://www.wsdot.wa.gov/mapsdata/geodatacatalog/default.htm
Hydrology	Wetlands	USFWS National Wetland Inventory	https://www.fws.gov/wetlands/nwi/
Conveyance	RSW_Pipes	City of Renton stormwater pipe network.	http://rentonwa.gov/government/default.aspx?id=29887
Conveyance	RSW_ Discharge	City of Renton stormwater pipe outfalls.	http://rentonwa.gov/government/default.aspx?id=29887
Conveyance	RSW_ OpenDrains	City of Renton stormwater open ditches.	http://rentonwa.gov/government/default.aspx?id=29887
Transportation	Streets	City of Renton Streets	http://www.wsdot.wa.gov/mapsdata/geodatacatalog/default.htm
Landuse	Landuse Types	Zoning and Property Use Types	http://rentonwa.gov/government/default.aspx?id=29887
Landuse	OpenSpace	Open undeveloped areas	http://rentonwa.gov/government/default.aspx?id=29887
Landuse	Parks	Multi-use parklands	http://rentonwa.gov/government/default.aspx?id=29887
Landuse	Candidate Stormwater Green Sites	Sites potentially available for green stormwater infrastructure	See workflow.
Terrain	Elevation Contours	Isolines of equal elevations	https://gdg.sc.egov.usda.gov/GDGOrder.aspx
Terrain	Soils	NRCS SSURGO Soils Data	https://gdg.sc.egov.usda.gov/GDGOrder.aspx

Table 1b. Renton Stormwater File Geodatabase Vector Datum, Projected and Geographic Coordinate Systems.

NAD_1983_HARN_StatePlane_Washington_North_FIPS_4601_Feet
Projection:
Lambert_Conformal_Conic
Geographic Coordinate System:
GCS_North_American_1983_HARN
Datum: D_North_American_1983_HARN
Spheroid: GRS_1980

Table 2a. Renton Stormwater File Geodatabase Datasets (raster).

Raster	Coverage	Description	Source
DEMd_Clip	Renton Basins	Elevation (feet)	https://gdg.sc.egov.usda.gov/GDGOrder.aspx
HillSha_Rent1_Clip	Renton Basins	Hillshade View	https://gdg.sc.egov.usda.gov/GDGOrder.aspx
Slope_Renton1	Renton Basins	Percent Slope	https://gdg.sc.egov.usda.gov/GDGOrder.aspx
maprecip_Clip2	Renton Basins	Mean Annual Rainfall	http://www.wsdot.wa.gov/mapsdata/geodatacatalog/default.htm

Table 2b. Renton Stormwater File Geodatabase Raster File Horizontal and Vertical Datums.

North American Datum (horizontal) of 1983 (NAD 83).
North American Vertical Datum of 1988 (NAVD 88).
National Elevation Data (NED) at a resolution of 1/3 arc-second (about 10-meters).

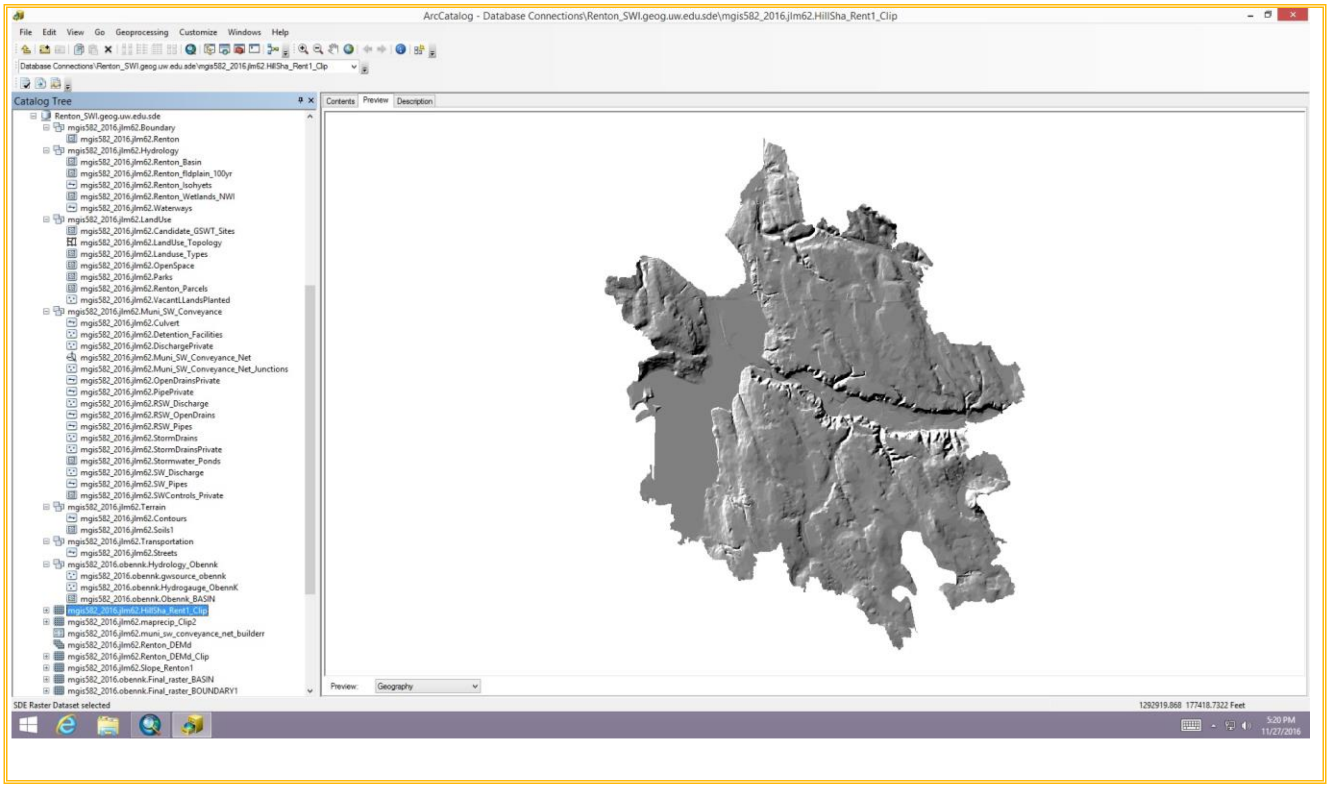


Figure 3. Renton SDE File Geodatabase.

4) Factors of interest regarding the spatial identification and mapping of such parcels include but are not necessarily limited to: 1) soil permeability and drainage class, 2) existing impervious surface, 3) existing point source stormwater discharge outlets, 4) vegetation cover, 5) land elevation, 6) land slope (degree and aspect), 7) annual precipitation, 8) road types and density, 9) existing streams and wetlands, 10) Federally listed anadromous fish runs, 11) existing stormwater conduit and treatment facilities, 12) zoning, 13) landuse, 14) land currently regulated under general stormwater permits, and 15) land ownership.

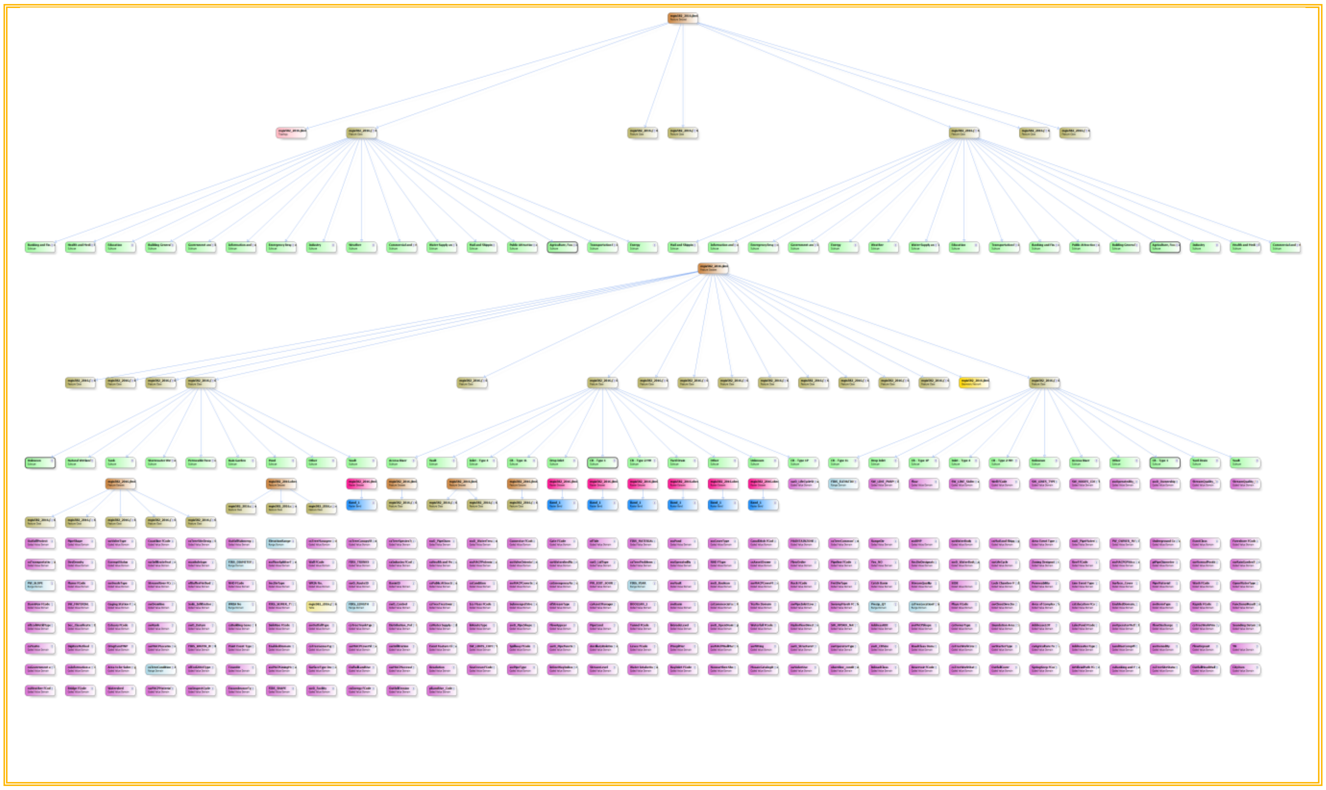


Figure 4. Renton SDE File Geodatabase Schema Diagram.

Geodatabase Design. A Spatial Data Engine (SDE) file geodatabase is created and used to hold these data (Table 1a, Table 1b, Figure 3, and Figure 4). Both vector and raster data were acquired by the authors and given common projected and geographic coordinate systems and horizontal datum. All data in the geodatabase are listed in Tables 1a and 2a along with hyperlinks to the web page sources they were downloaded from.

The data collectively provide a representation of the features associated with the area draining into the City of Renton that may in some way contribute to the quantity, quality, and periodicity of stormwater flowing both on the land surface and in a subsurface stormwater pipe network. The data are organized by two areas of interest: 1) the City of Renton – AOI-1 and 2) the area of land draining into and through the City of Renton – AOI-2.

Elevation and slope of the land surface play a significant role in the amount of rainfall and flow direction of surface water. Six digital elevation models at 10-meter resolution were downloaded, placed in a raster mosaic, classified, and clipped to AOI-2. Spatial analysis surface tools were then used to derive 10-foot elevation contour intervals of that area (Figures 5 and 6). The vertical datum is NAVD 1988.

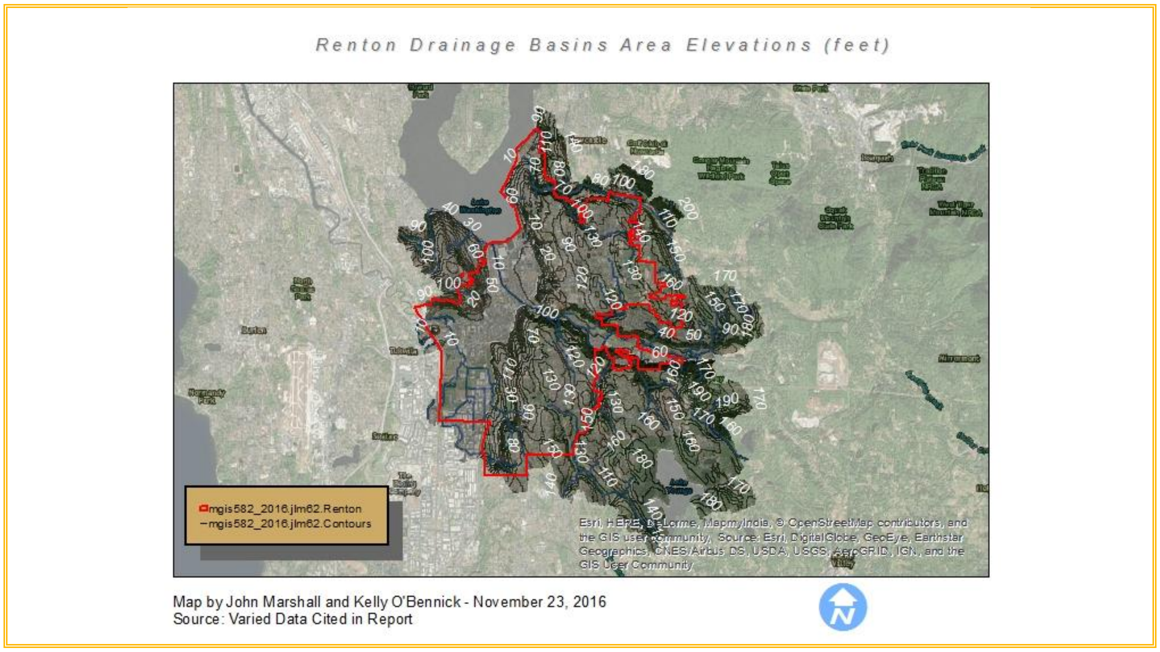


Figure 5. Renton Elevation Contours (NAVD 1988).

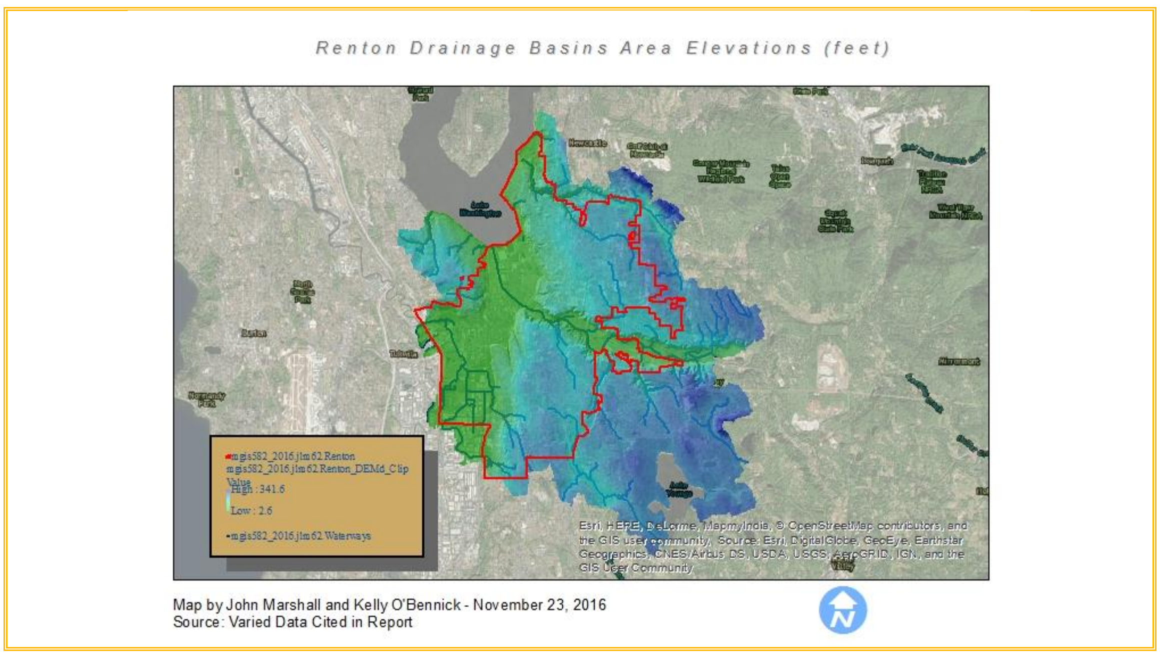


Figure 6. Renton Elevation Classification (NAVD 1988).

A raster containing cell values for mean annual rainfall was downloaded and used to represent annual precipitation in and immediately surrounding AOI-2. Spatial Analyst surface tools to derive 5-inch/year isohyet intervals (Figures 7 and 8).

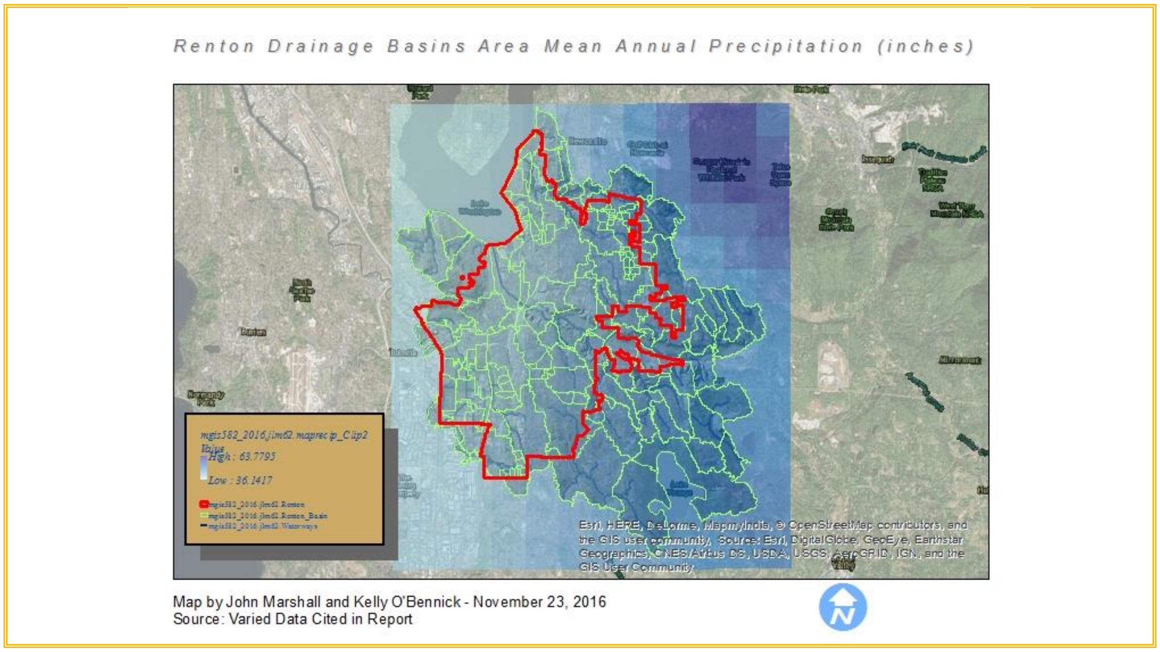


Figure 7. City of Renton Mean Annual Precipitation and Drainage basins.

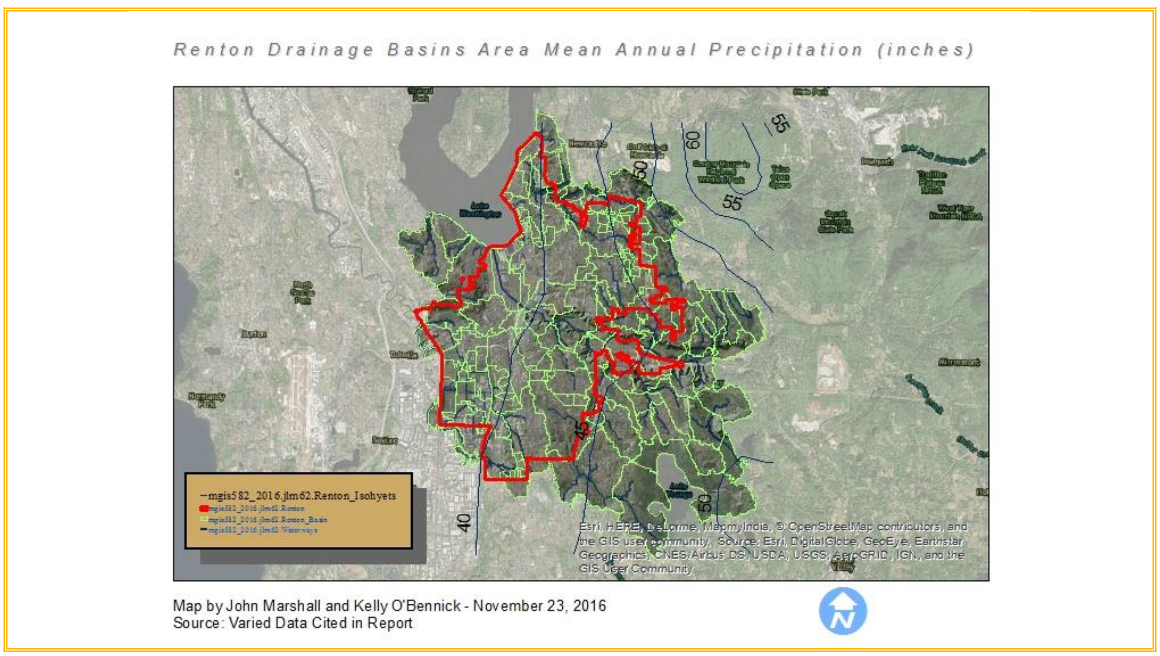
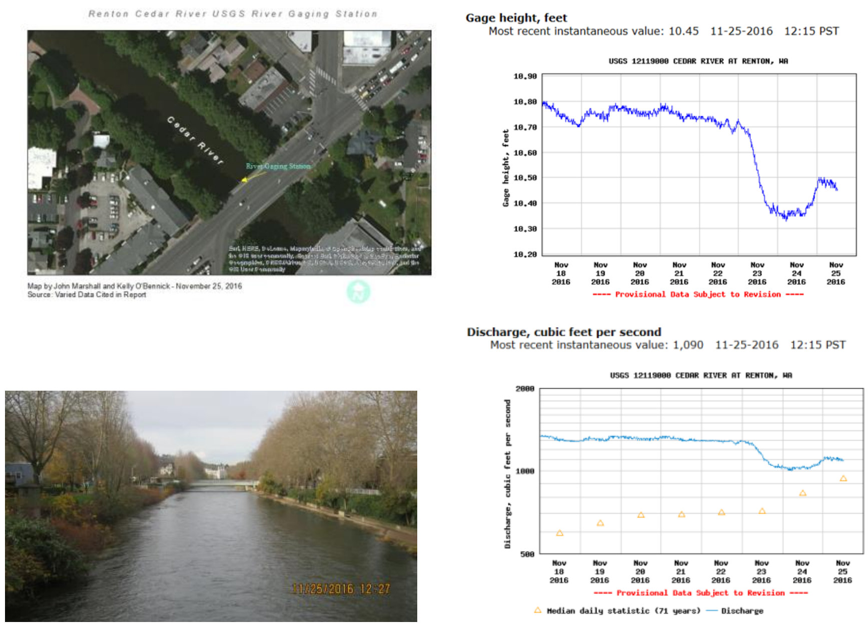


Figure 8. City of Renton Mean Annual Precipitation and Drainage basins.

Figure 9 displays the location of a US Geological Survey (USGS) river gage for the Cedar River where it flows under Bronson Way North in the City of Renton, about 1.5-miles upstream of where it flows into south Lake Washington. This river gage is electronically reporting river height in feet and flow volume in cubic feet per second to a remote webpage posted for public access. This data is also posted in Figure 9 for an eight-day time period and allowed the authors to take a photograph to visually display the Cedar River water levels at the gage site less than 15-minutes after the last automated gage data recording was reported on the USGS web page. Figure 10 displays the average monthly rainfall and temperature for the City of Renton, illustrating late fall and winter as the wettest period of the year and a yearly summer draught.

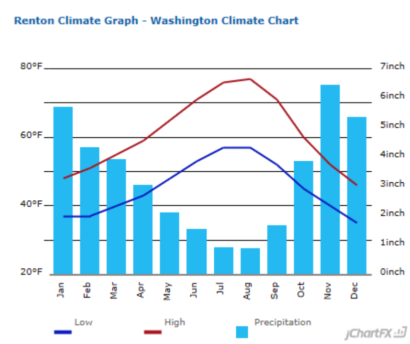


Source: http://waterdata.usgs.gov/nwis/uv?site_no=12119000

Figure 9. Discharge and Gage Height of Cedar River in Renton, Washington on November 25, 2016.

	Jan	Feb	Mar	Apr	May	Jun
Average high in °F:	48	51	55	59	65	71
Average low in °F:	37	37	40	43	48	53
Av. precipitation in inch:	5.71	4.33	3.94	3.07	2.13	1.57
Days with precipitation:	-	-	-	-	-	-
Hours of sunshine:	-	-	-	-	-	-

	Jul	Aug	Sep	Oct	Nov	Dec
Average high in °F:	76	77	71	60	52	46
Average low in °F:	57	57	52	45	40	35
Av. precipitation in inch:	0.94	0.91	1.69	3.86	6.46	5.39



Source: http://www.usclimatedata.com/climate/renton/washington/united-states/uswa0824

Figure 10. Renton Average Annual Precipitation and Temperature.

The City of Renton maintains a web page providing access to a variety of GIS data including the City's public and private stormwater piping system. Figure 11 illustrates the complexity of these interconnected piping networks running mostly subsurface over the entire city (AOI-1). While the attribute tables of both pipe feature classes contain pipe segment start and end elevations, data does appear to be consistently entered for all segments and depending on where in the city pipes are located, the vertical elevations may be referenced to different datums. Therefore, running a network to discern flow direction seemed problematic. Fortunately, the City of Renton GIS department uses a cartographic convention for these feature classes that basically states when applying the symbology to this line feature class to represent flow direction, "*all direction arrows point right*." We tested this convention on the line segments representing surface flows against our DEM and, with one exception (a side channel on the Cedar River), found the water flow to correctly being displayed as moving downhill.

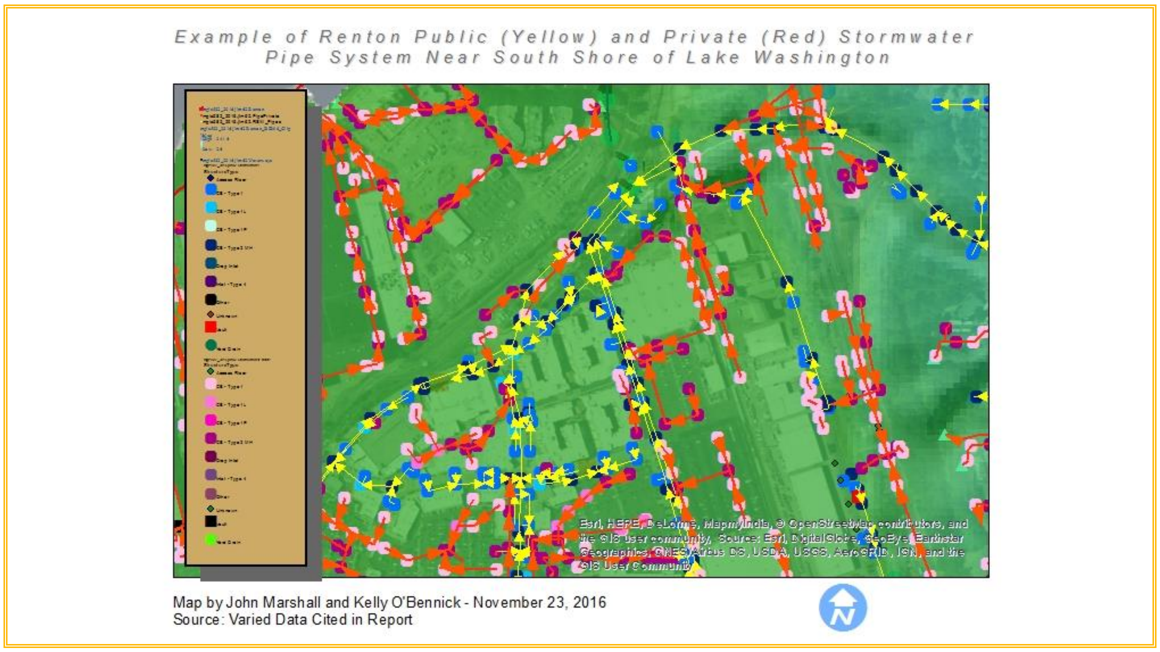
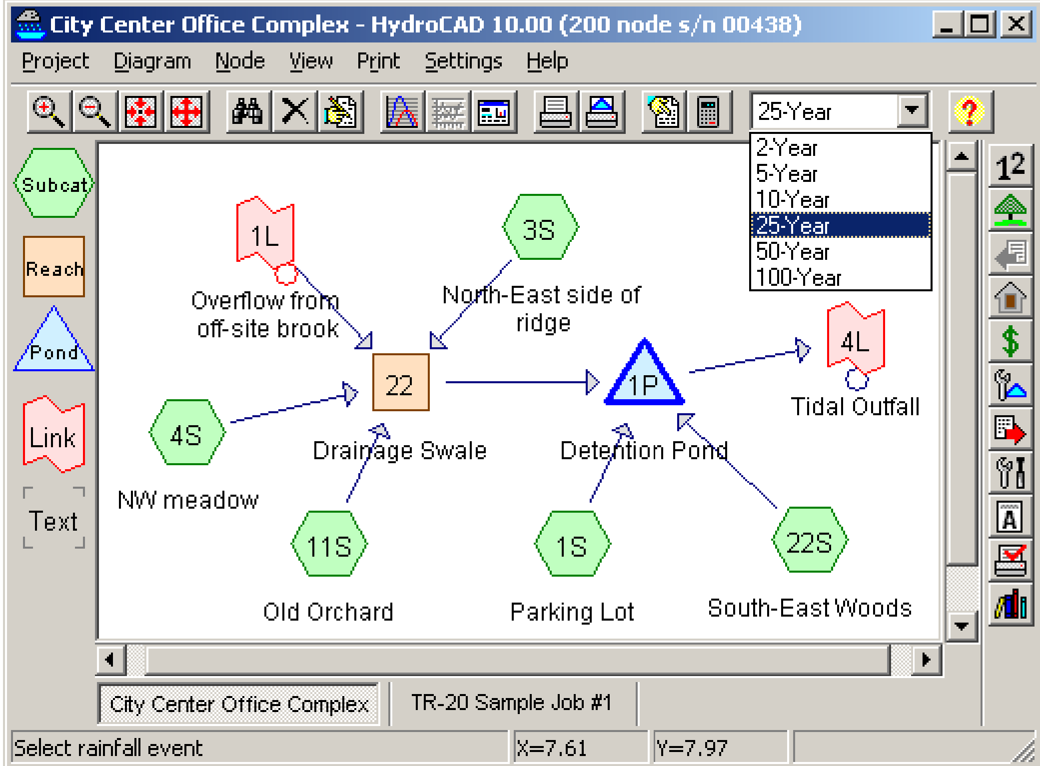


Figure 11. Example of Renton Public and Private Stormwater Pipe Network.

It should also be noted that the City of Renton GIS department reports the stormwater pipe feature classes as "works in progress" and not necessarily completed or spatially accurately represented in any give area of the network. Nevertheless, we considered it an adequate representation for the purposes of our class project and this report.

Given the density of stormwater catchments (storm drains) in the City of Renton AOI-1 (see semi-circular features in Figure 11), and the largely developed character of the City, it is assumed that the largest proportion of urban surface origin stormwater flow moves through the mostly underground public and private stormwater pipes. It is also assumed that a significant portion, if not most, of new stormwater green infrastructure will likely be designed to connect into this stormwater pipe network. Under these assumptions our workgroup decided to use the stormwater pipe network as the focal spatial data for centering our searches for land parcels with opportunities to provide green stormwater infrastructure.

We briefly considered possibly using specialized software to somehow model stormwater flow volumes and possibly even stormwater control treatment parameters within the pipe network. But the only software we found (see Figure 12) potentially appropriate for such tasks appeared to be designed primarily for application at the individual project level and would have required considerable training outside of the scope of this course for us to apply it with any confidence of achieving reliable results.



http://hydrocad.net/

Figure 12. Example of Stormwater Network Modeling Software (HydroCAD).

One advantage of having the Renton stormwater pipe data is that it also contained classes and subtypes of stormwater controls associated with the pipe network that, at least for a limited geographic area, we could visit and field verify presence and overall designs with the GIS data (see Figures 13, 14, and 15).

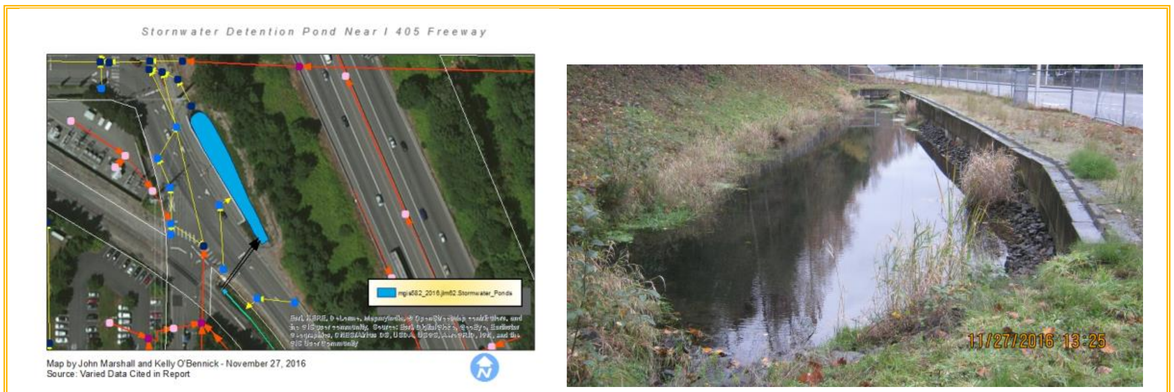
Field reconnaissance of several of these features revealed structures that were likely put into use during the early days of stormwater control design. This conclusion is based primarily on the evidence of hard engineering dominating the designs on most of the facilities. Depending on the facility, they range from displaying varying aspects of green infrastructure design (e.g., partially containing pervious surfaces and aquatic vegetation) to being constructed almost entirely out of concrete and metal.

47.491694, 122.200046

Figure 13. Example of Renton Stormwater Detention Pond.

47.495285, -122.197991

Figure 14. Example of Renton Stormwater Detention Pond.



47.495342, -122.194065

Figure 15. Example of Renton Stormwater Detention Pond.

These stormwater facilities occupy an area that scores as high importance for water flow assessment while also being at a high level of degradation (Stanley et al 2013, Stanley et al 2016, Wilhere et al 2013, WDOE 2016) in the Puget Sound Characterization.

Alternative Workflows. Most of the data acquired for our SDE geodatabase is not now used in the alternative workflows (Tables 3 and 5) used to compile this report. Two alternative workflows, primarily based on the proximity to the stormwater pipe network and public parcel ownership as selection criteria, were developed to identify candidate green infrastructure site locations inside the City of Renton (see Tables 3, 4, 5, and 6). Workflow Alternative 1 is intended to error on the side of inclusion by casting a wide net for candidate site selection and should not prematurely exclude viable candidate sites.

Table 3. Workflow Alternative 1.

Step 1.	Select by location parcels within 100-feet of a public stormwater pipe.
Step 2.	Of the selected parcels select the parcels with centroid inside an open space feature.
Step 3.	Export selected parcels to first intermediate open space proximate to stormwater pipe infrastructure feature class;
Step 4.	Select by location parcels within 100-feet of a public stormwater pipe;
Step 5.	Of the selected parcels select the parcels with centroid inside a park feature;
Step 6.	Export selected parcels to second intermediate park proximate to stormwater pipe infrastructure feature class;
Step 7.	Merge the two intermediate feature classes to create third single intermediate feature class
Step 8.	Select by attribute parcels in City of Renton, King County, or State of Washington ownership.
Step 9.	Export selected parcels to final feature class representing candidate sites for the protection of existing or creation of new stormwater green infrastructure.

Table 4. Draft Results Alternative 1.

NumberSites	Acres	MaxSize (acres)	MajSize (acres)
277	1,524.5	52.5	< 1.0

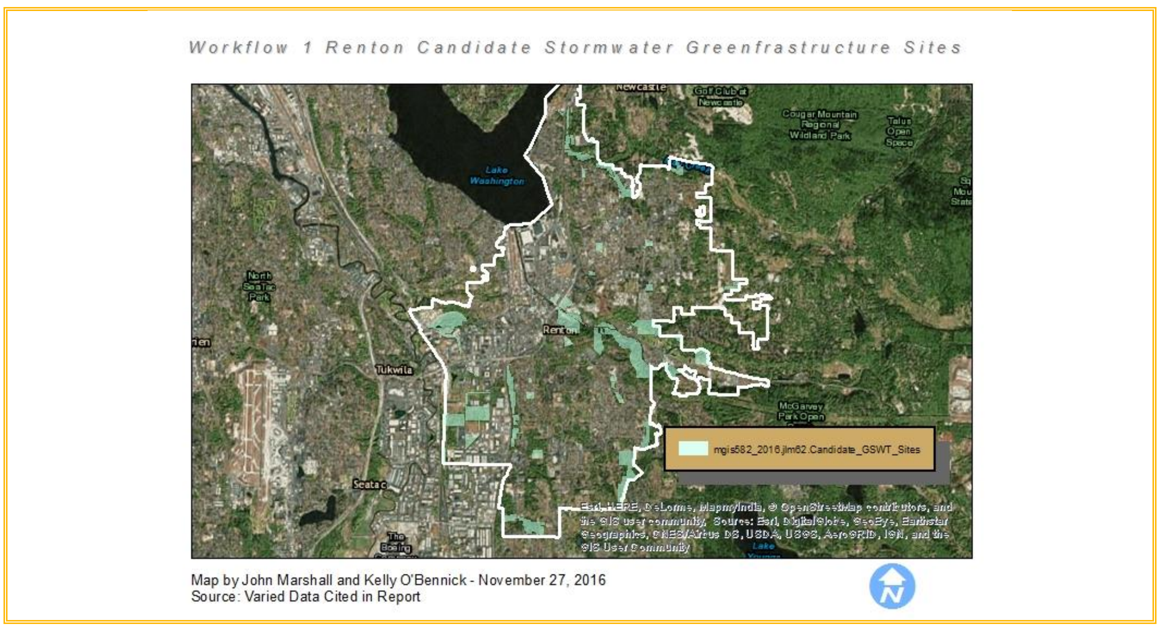


Figure 16. Alternative Workflow 1 Renton Green Stormwater Infrastructure Sites.

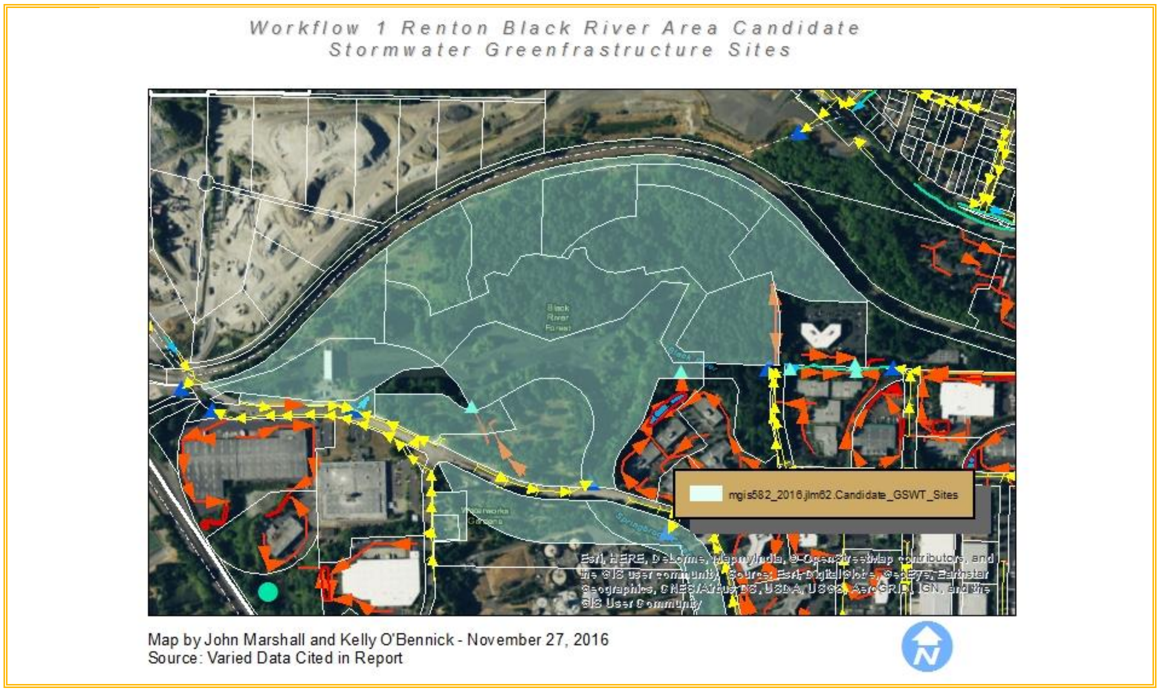


Figure 17. Alternative Workflow 1 Renton Black River Area.

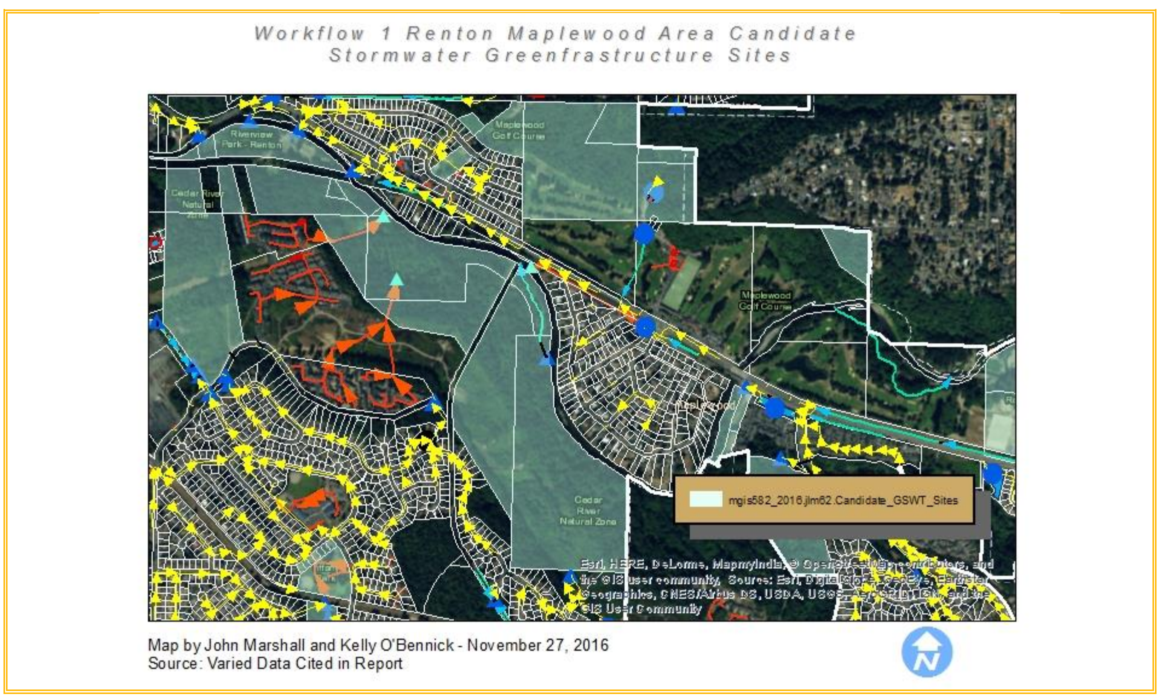


Figure 18. Alternative Workflow 1 Renton Maplewood Area.

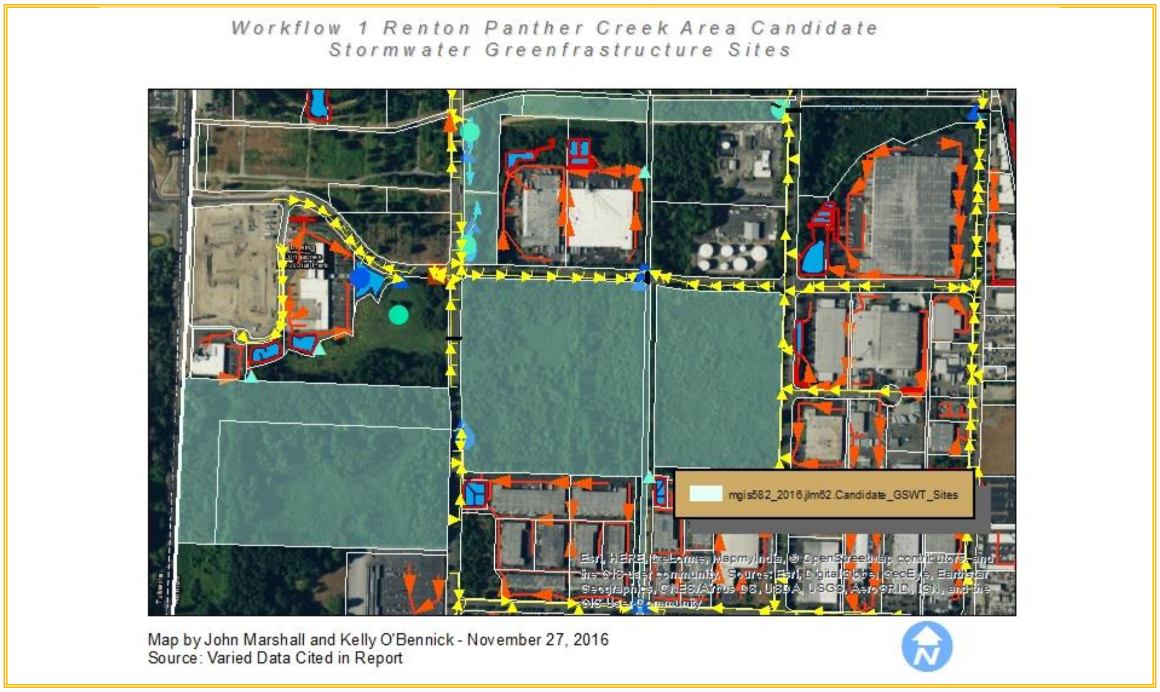


Figure 19. Alternative Workflow 1 Renton Panther Creek Area.

Workflow Alternative 2 is intended to be a slightly more exclusive screen for candidate green Stormwater infrastructure sites by decreasing the proximate parcel distance threshold by 50%, restricting to private stormwater pipes, and selecting by attribute only those selected park and open space parcels owned by the City of Renton.

Table 5. Workflow Alternative 2.

Step 1.	Select by location parcels within 50-feet of a private stormwater pipe.
Step 2.	Of the selected parcels select the parcels with centroid inside an open space feature.
Step 3.	Export selected parcels to first intermediate open space proximate to stormwater pipe infrastructure feature class;
Step 4.	Select by location parcels within 50-feet of a private stormwater pipe;
Step 5.	Of the selected parcels select the parcels with centroid inside a park feature;
Step 6.	Export selected parcels to second intermediate park proximate to stormwater pipe infrastructure feature class;
Step 7.	Merge the two intermediate feature classes to create third single intermediate feature class
Step 8.	Select by attribute parcels in City of Renton ownership.
Step 9.	Export selected parcels to final feature class representing candidate sites for the protection of existing or creation of new stormwater green infrastructure.

Table 6. Draft Results Alternative 2

NumberSites	Acres	MaxSize (acres)	MajSize (acres)
119	753.1	44.1	< 0.5

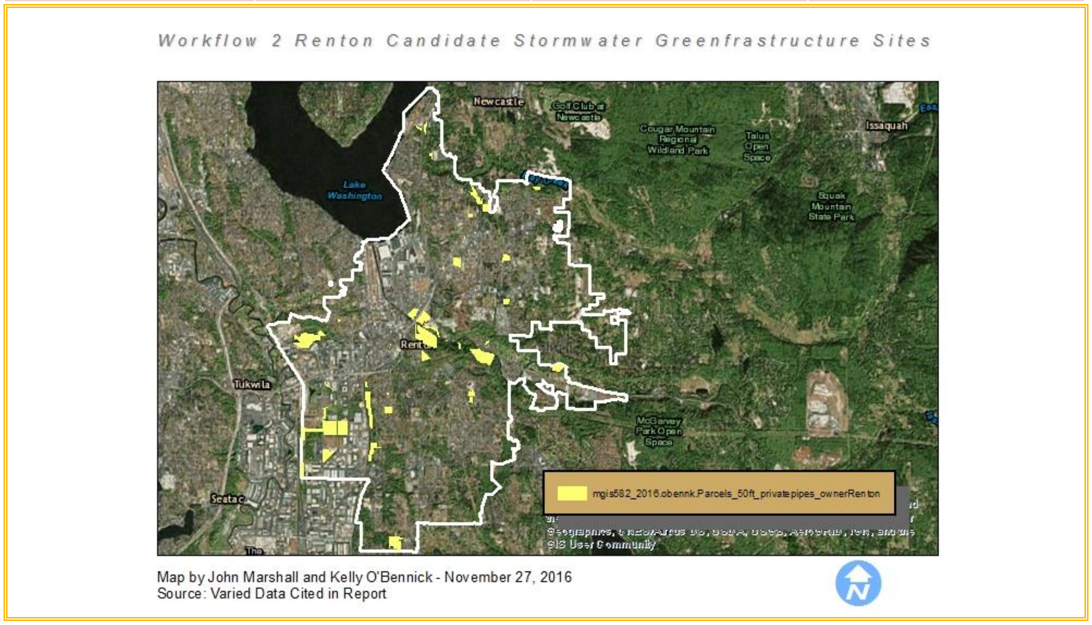


Figure 20. Alternative Workflow 2 Renton Green Stormwater Infrastructure Sites.

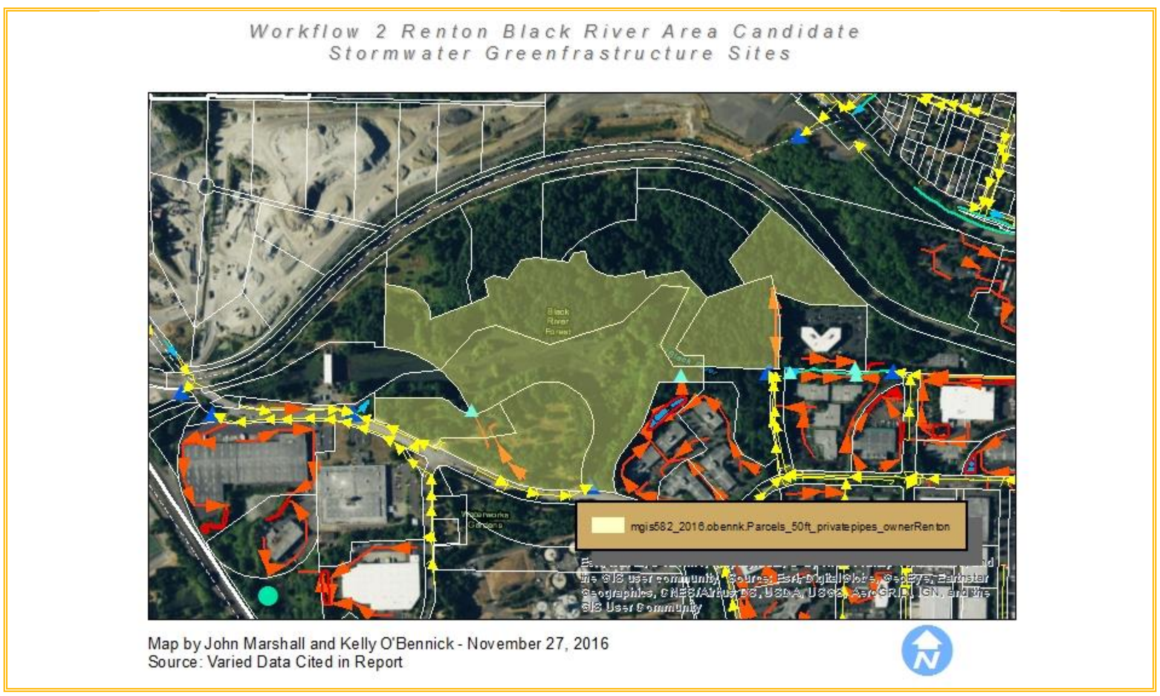


Figure 21. Alternative Workflow 2 Renton Black River Area.

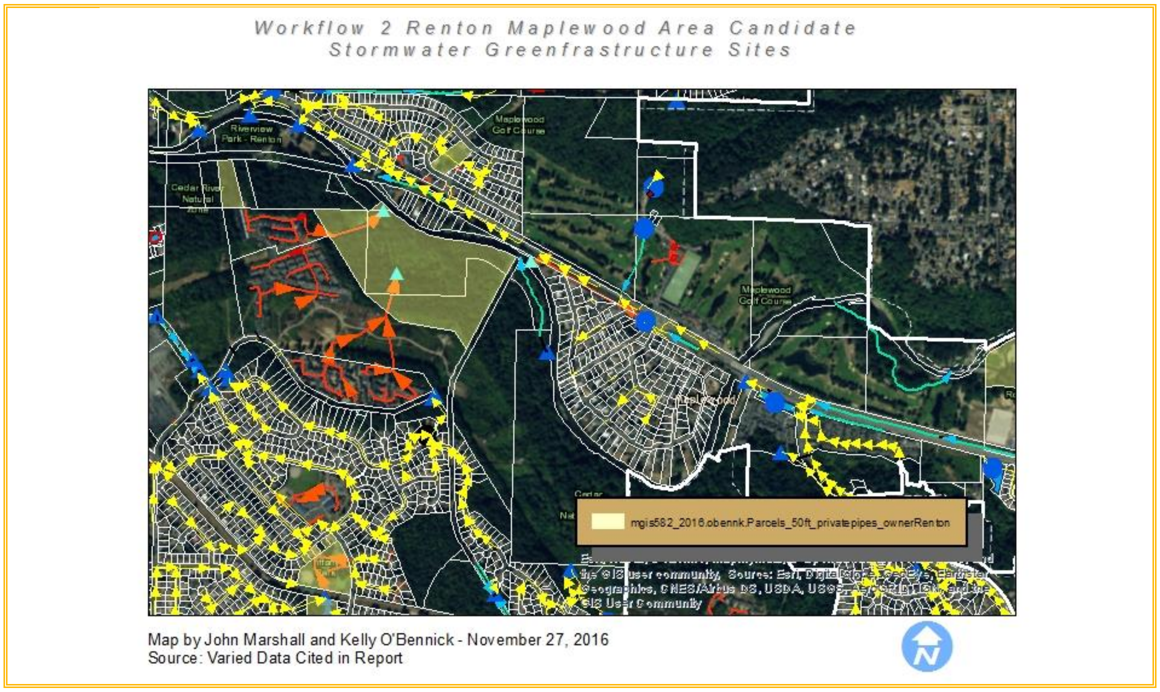


Figure 22. Alternative Workflow 2 Renton Maplewood Area.

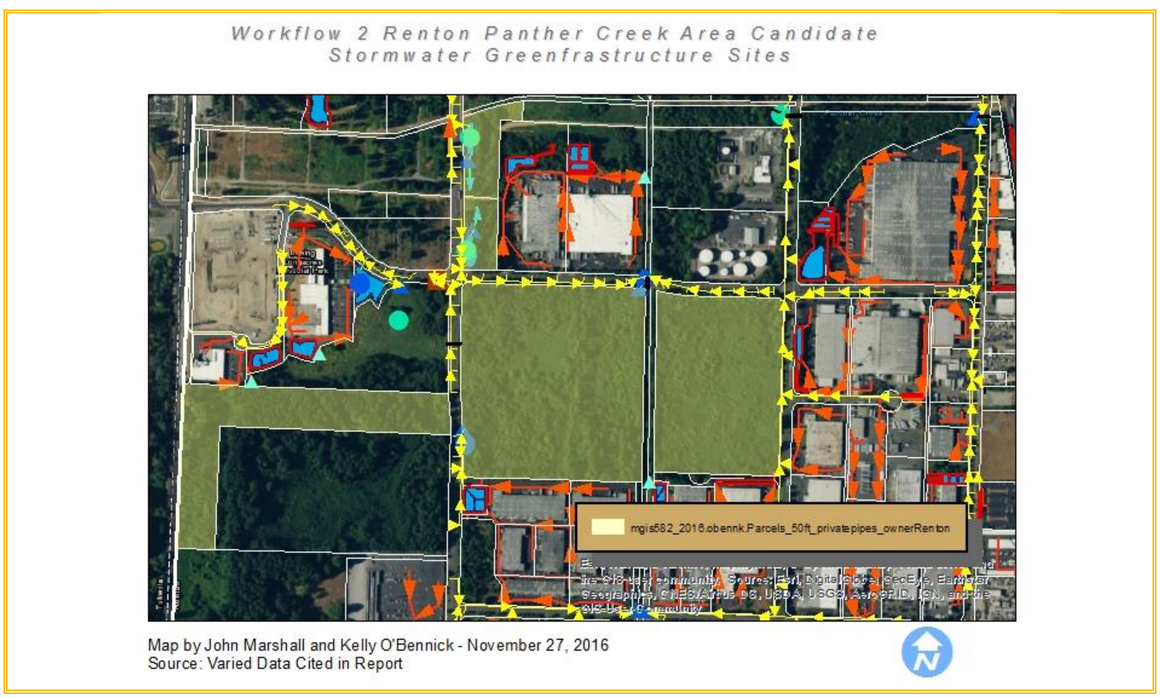


Figure 23. Alternative Workflow 2 Renton Panther Creek Area.

Conclusion

Two alternative workflows based on stormwater pipeline proximity to publicly owned parkland and open space were designed to select and represent a list of potential candidate stormwater greenfrastructure sites in the City of Renton. Workflow Alternative 1 provides a wider inclusive inventory list of 277 candidate publicly owned sites covering over 1,500-acres. Workflow Alternative 2 provides a more exclusive inventory list of 119 candidate sites owned by the City of Renton covering over 750-acres. Limited search and selection criteria were used and there was no attempt to classify candidate sites by their relative fitness matches with specific stormwater control types.

Given the legacy nature of many of the observed existing stormwater control facilities in the City Renton, there may be opportunities and regulatory incentives for upgrading some or all of these facilities to be in better conformance with modern green stormwater infrastructure design and performance.

Problems Encountered. Our workgroup could not obtain and render last return (bare earth) high resolution LiDAR data for either AOI-1 or AOI-2. We unwittingly acquired and rendered first return high resolution LiDAR but it was of course not able to be used with respect to our project's design objectives, which required ground surface elevation data. We did acquire and render six 10-meter resolution DEMs, which we placed in a mosaic and clipped to our AOI-2 drainage basins to represent the terrain in both AOI-1 and AOI-2.

We also had problems coordinating editing sessions in the Virtual Machine Spatial Data Engine environments and often found that we were locked out of our geodatabase when attempting to manage our data. To this day, we still do not know for certain why these locks occurred within the context of the versioning and permission procedures we applied or exactly how they were technically resolved. We find this to be especially unfortunate given one of the primary objectives of this Geography 582 course was to provide students with instructions on how to work cooperatively and seamlessly with geospatial data in an enterprise like environment.

Future Considerations. Near the end of December 2016 most of the municipalities in King County, including Renton, will enter Phase II of their municipal stormwater permits (Taylor et al 2013, WDOE 2014a, WDOE 2014b, WDOE 2014c, City of Renton 2010, City of Renton 2016). All new development and redevelopment in those cities will be required to meet a higher bar for installing green stormwater infrastructure controls to off-set the adverse effects of their development. Assuming most of the required greenfrastructure will be established on-site, use of an inventory of publicly owned open space and parkland near existing stormwater infrastructure may not be effectively incentivized by the regulations. Regulatory programs tend to target a "no-net-loss" ideology (Stanley et al 2013) using project-by-project concepts of pre-development and post-development and are therefore, most likely to focus remediation actions on new and legacy stormwater infrastructure. To achieve some benchmark of historical recovery for a region like the Puget Sound, government grant programs will likely be required to fund protection of existing and development of new green stormwater infrastructure above and beyond that which is required in the National Pollution Discharge Elimination System (NPDES) stormwater regulatory program. Inventories like those generated in this report are more likely to be used to help facilitate broader grant programs such as these.

Resources

Cammermayer, J.W., Chechowitz, N. and R. R. Horner 2000. *Vegetated stormwater facility maintenance*. Washington State Transportation Center (TRAC), University of Washington, Research Project T1802, Task 7, Seattle, Washington.

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