

DRAINAGE SYSTEMS ANALYSIS

Flooding Topic Area | Creeks Analysis

October 9, 2020

Seattle Public Utilities

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Salmon in Longfellow Creek, Seattle. Holli Margell, 2009. http://nativelightphoto.com/

Thornton Creek Confluence Restoration, Seattle. Natural Systems Design, 2014. http://naturaldes.com

Flooding in South Park, Seattle. Sheila Harrison, Seattle Public Utlities, 2009.

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Flooding Topic Area

Technical Memorandum

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Abbreviations

1D	one-dimensional
2D	two-dimensional
BC	Brown and Caldwell
City	City of Seattle (organization)
Consultant	Brown and Caldwell
DEM	digital elevation model
DSA	Drainage System Analysis
DWW	Drainage and Wastewater
FEMA	Federal Emergency Management Agency
FIRM	Flood Insurance Rate Map
GIS	geographic information system
HARN	High Accuracy Reference Network
LiDAR	Light Detection and Ranging
LOB	line of business within Seattle Public Utilities
MHHW	mean higher high water
NAD83	North American Datum of 1983
NAVD 88	North American Vertical Datum of 1988
NRC	National Research Council
OPCD	Office of Planning and Community Development
ROW	right-of-way
SDOT	Seattle Department of Transportation
SPU	Seattle Public Utilities
SWMM	Storm Water Management Model
TM	technical memorandum

1. Introduction

Seattle Public Utilities (SPU) is completing a Drainage System Analysis (DSA) to provide data collection and technical analyses that support the development of the Shape Our Water Plan (formerly the *Vision Plan* and *Integrated System Plan)* for the Drainage and Wastewater (DWW) line of business (LOB). The DSA will compile and update existing information related to SPU's drainage system and receiving waters, as well as perform new analyses that focus on flooding, climate change impacts, and water quality issues. The DSA efforts are divided into multiple topic areas, including a flooding topic area.

SPU contracted with Brown and Caldwell (Consultant) to perform technical analyses for the DSA flooding topic area. Key objectives for the flooding topic area include:

- Develop a prioritized inventory of drainage system capacity risk areas.
- Define Performance Thresholds for the drainage system and complete modeling to evaluate the capacity under existing and future conditions.
- Estimate inundation extent and develop risk maps for extreme storm events, sea level rise, and creek flooding.
- Estimate runoff and flow in areas served by ditches and culverts.
- Calculate flow metrics in creek watersheds and prioritize areas for runoff reduction to reduce erosive flows to creeks.

While some analyses focus on the performance of the drainage system that SPU owns and operates, others, including this analysis, evaluate risks beyond the performance of that system.

The primary goal of this analysis is to identify and map areas where flooding could occur along creeks. The analysis covers the five major creeks within the city for existing conditions in terms of both watershed conditions and climate conditions. Key objectives include:

- Devise an approach that uses existing information to map areas at risk to creek flooding.
- Apply the approach to estimate inundation extent due to creek flooding for the following creeks: Longfellow Creek, Taylor Creek, Fauntleroy Creek, Piper's Creek, and Thornton Creek.
- Perform geospatial mapping analyses to develop a risk map for areas at risk to creek flooding.

This technical memorandum (TM) describes technical methods and summarizes the results of the Creeks Analysis. Section 2 describes the background information used for this analysis. Section 3 describes the methods used to map the inundation extent. Section 4 describes the risk mapping analyses. Section 5 summarizes the results. Section 6 describes the limitations of the analysis.

2. Background Information

The analysis described herein combines flood inundation areas developed from multiple existing data sources to map the risk area. No new modeling was completed for this analysis. These data sources include Federal Emergency Management Agency (FEMA) Flood Insurance Rate Maps (FIRM), draft flood study, Storm Water Management Model (SWMM) modeling results, and results from a parallel DSA analysis of extreme storm events risk mapping. The number and extent of available data sources varied for each creek basin (Table 2-1). The follow sections provide a summary of the available data.

Table 2-1. Available Data Sources by Creek

Data sources	Year of model	Fauntleroy	Longfellow	Taylor	Piper's	Thornton
SWMM Models	2016-2018	✓	✓	✓	✓	✓
Draft flood study	2010	--	✓	--	--	--
Preliminary FIRM	2008	--	✓	--	✓[a]	✓
Effective FIRM	1986	--	✓	--	✓[a]	✓
Extreme storms	2020	✓	✓	✓	✓	✓

a. Not based on modeling

2.1 FIRM and Draft Flood Study Mapping

The effective FIRM for the City of Seattle, as part of King County, was first adopted in 1995. The FIRMs establish legally binding restrictions on development, served as the basis for determining flood risk to structures, and are used to calculate flood insurance rates. The effective FIRM was issued originally as a paper map. It was hand digitized into ArcGIS data format. A 100-year floodplain was established for Longfellow, Piper's, and Thornton creeks. For all three creeks, there are currently sections of the creek that do not align with the effective FIRM used for this analysis. No FIRM data exists for Taylor or Fauntleroy creeks.

For Longfellow Creek, the 100-year floodplain was established through modeling. In 2010, detailed hydrologic and hydraulic modeling to update the floodplain was completed. Draft results were prepared, but they were not finalized nor submitted to FEMA. These results are referred to in this memo as the draft flood study. Longfellow also has Preliminary FIRM data – data submitted to FEMA to update the effective FIRM, but not yet approved by FEMA. The draft flood study data are considered more accurate and better align with the creek, therefore the Preliminary FIRM data were not used in this analysis.

For Piper's Creek, the 100-year floodplain was established through approximate methods that did not include modeling or estimating flood elevations. Piper's Creek also has Preliminary FIRM data. It was drafted with modern map-making techniques and issued in digital format which resulted in floodplain extent that differs from the effective FIRM.

For Thornton Creek, the 100-year floodplain was established through modeling. Thornton Creek also has Preliminary FIRM data. In 2010, detailed hydrologic and hydraulic modeling was completed to assess flood risk after a major storm event in 2007 (Northwest Hydraulic Consultants, Inc., 2010). Modeling was completed to meet FEMA requirements and they were submitted to FEMA and are the Preliminary FIRM.

After this analysis was completed, FEMA adopted the Preliminary FIRM as the effective FIRM (August 2020).

2.2 SWMM Modeling

Drainage models for the City of Seattle have been developed and updated in multiple phases. The level of detail in each model varies based on the data availability at the time it was developed or updated and the hydraulic complexity of the drainage system. Information specific to each drainage model used for the DSA is provided in Table 2-2.

Table 2-2. DSA SWMM Models and Creek Representation

Creek	Most recent update	Number of calibration locations	Basis for channel cross-sections	Most recent model development report
Fauntleroy	2018	2	2-ft contours	Aqualyze, Inc, 2018
Longfellow	2015	5	2-ft contours	Aqualyze, Inc, 2016
Taylor	2016	1	Upstream of 68th Ave S: 2-ft contours Downstream of 68th Ave S: HEC-RAS model data, based on creek survey data	Osborn Consulting Inc, 2016
Piper's	2015	6	2-ft contours	Aqualyze, Inc, 2016
Thornton	2018	37	HEC-RAS model data were used for the lower reaches, based on creek survey data; upper reaches and tributaries were based on other available data sources (e.g., Facility Operations and 2-ft contours).	Aqualyze, Inc, 2018

As part of the 2010 Thornton Creek modeling effort, a steady-state HEC-RAS model was developed including 398 surveyed creek cross-sections (Northwest Hydraulic Consultants, Inc., 2010). The cross-sections were incorporated into the SWMM Model during the 2018 update. This update also included incorporating major restoration projects (Kingfisher Natural Area, Meadowbrook Pond Dredging) as well as the portion of the system served by ditches and culverts (Aqualyze, Inc, 2018).

All models were run for a set of synthetic 24-hour storms for the capacity analysis completed for the DSA (Brown and Caldwell 2020a). The results from the 100-year, 24-hour storm event were used in this analysis. Based on past creek flooding proximity to residences and streets during smaller rainfall events in the Longfellow and Thornton creek basins, the results from the 25-year, 24-hour storm event were also used in these basins.

2.3 Extreme Storms

For the DSA extreme storms risk mapping, the Consultant performed a 2-dimensional (2D) horizontal flow analysis using CADDIES 2D modeling software to simulate surface flooding caused by extreme storms (Brown and Caldwell 2020b). The modeling is based on a land surface digital elevation model (DEM) (Quantum Spatial 2016). The surface flow modeling produced city-wide geospatial datasets representing peak water surface elevations and flooding depths. Raw model output was refined to create an inundation extent (Brown and Caldwell 2020b). The results from a historical 100-year event (December 3, 2007), with 5.61 inches of rain falling in 24 hours, were used in this analysis.

The surface flow modeling captures flooding due to overland flow but the model lacks representation of creeks and culverts. This results in over-prediction of flood depths where the channel is deeply incised below the elevation shown on the DEM and behind embankments that are pierced by culverts. This can also result in inundation surrounding piped reaches, which may represent inundation if the pipe were removed and the creek daylighted.

3. Inundation Mapping

Using the available data, an inundation extent was mapped for each of the five creeks. The mapped extent was limited to the stormwater drainage basin as represented in the SWMM models, with the exception of the Thorton creek basin where Preliminary FIRM data existed downstream of the SWMM model extent. The following sections describe how each of the existing datasets were used to map an inundation extent. These inundation extents were then combined to develop a single extent for each creek.

3.1 FIRMs and Draft Flood Study

As noted above, FIRMs or draft flood studies are only available for three of the creeks: Longfellow, Piper's, and Thornton. The FIRMs were used as an estimate of inundation extent. For Thornton and Piper's creeks the Preliminary and the effective FIRMs were both used. For Longfellow Creek the draft flood study (which is considered more accurate than the Preliminary FIRM) and effective FIRM were used. Depth estimates are only partially available and were not used in this analysis.

3.2 Extrapolating SWMM Model Results

The SWMM models of SPU's drainage system are 1-dimensional (1D) models that convey surface runoff and groundwater infiltration through a series of links and nodes representing pipes, creeks, ditches, and culverts. While they capture the hydraulics of open channels, culverts, and drainage pipes, they do not capture overland flow and only report water depth in the nodes.

For this analysis, 1D results were extrapolated onto a land surface DEM (Quantum Spatial 2016). The DEM was resampled to a 4-ft grid using the same points as the extreme storms analysis (Brown and Caldwell 2020a) land surface. The 4-ft grid was used unadjusted; it was neither raised to reflect the impact of the built environment (i.e. buildings) nor lowered to reflect creek channel bottoms (which are not captured in the land surface DEM).

Because SWMM is a 1D model, bends in creeks cannot be explicitly modeled. Between each node, the creek is modeled with one straight channel section. Appendix A shows the SWMM representation of each creek. To extrapolate the 1D results from the nodes, the SWMM model results were mapped to the creek channel locations they represent, as shown in the Urban Watercourse GIS data (downloaded 8/27/19). Transects were drawn in GIS, perpendicular to the creek channel locations, and the lowest point in the land surface DEM along the transect was recorded. The SWMM-predicted maximum water depth was added to the elevation at the lowest recorded point. These extrapolated flood elevations were then interpolated to create a water surface (an inundation area grid). The DEM was subtracted from the water surface to create an estimated flood depth grid.

This approximate method does not conserve flood volume, and over-predicts in areas where (1) narrow tributaries cut across a hillside, and (2) the actual floodplain is significantly wider than the channel cross-section in the model.

3.3 Using Extreme Storms Results

The extreme storms analysis results provided a citywide gridded dataset of flood depth. To select inundation pertaining to creek flooding, a buffer was created around the creek channel locations as shown in the Urban Watercourse GIS data (downloaded 8/27/19). The size of the buffer was determined from the widest portion of the inundation area extrapolated from the SWMM results. Areas where any portion of extreme storms flood inundation intersected the buffer were retained and included in the inundation extent.

4. Risk Scoring

SPU developed an approach to calculating risk scores based on factors of consequence, likelihood, and equity. Scoring methods and criteria were developed based on methods outlined in SPU's *Risk Assessment Framework* (SPU 2007), staff subject matter expertise, and a review of past prioritization criteria developed and applied by SPU (SPU 2020). The basic equation for calculating risk scores is:

$$Risk\ Score\ = (Conseqence\ Score\ \times\ Likelihood\ Score) + Equity\ Score$$

where each component has a maximum score of 5, and the resultant maximum possible risk score is 30.

The following sections describe the scoring process for inundation extents within the city, based on component scores for the consequence, likelihood, and equity. Detailed workflow charts of GIS processes for scoring and risk mapping are provided in Appendix B.

4.1 Consequence Score

The depth and inundation grids described in Section 3 and other established consequence data were used to calculate the consequence scores. The consequence score for any single location (i.e., 4-ft cell within a spatial grid) was calculated by adding a score associated with the depth of inundation (depth score) with four other component scores related to areas with potentially high consequences of flooding as follows:

$$\begin{aligned} &Consequence\ Score \\ &\quad = Depth\ Score + Confidence\ Score + \ High\text{-}Use\ Area\ Score \\ &\quad + Critical\ Facility\ Score\ +\ Major\ Transportation\ Route\ Score \end{aligned}$$

- **Depth.** Only two data sources provided an estimate depth: extreme storms analysis results and extrapolating SWMM results. In general, the depth estimates produced by the extreme storms analysis are more certain than those estimated by the SWMM extrapolation process; although there are cases where the extreme storms results are less reliable than the SWMM extrapolation, as the extreme storms analysis did not explicitly account for below ground conveyance such as culverts. Therefore, within the extreme storms inundation extent, the depth from that analysis was used. For areas outside that extent and within the SWMM inundation extent, the depth from the extrapolation was used.

  The depth scores were assigned using the relationship shown in Figure 4-1, where if there was no estimated depth because it is within a FIRM inundation extent solely, it was assigned the minimum score of 1.

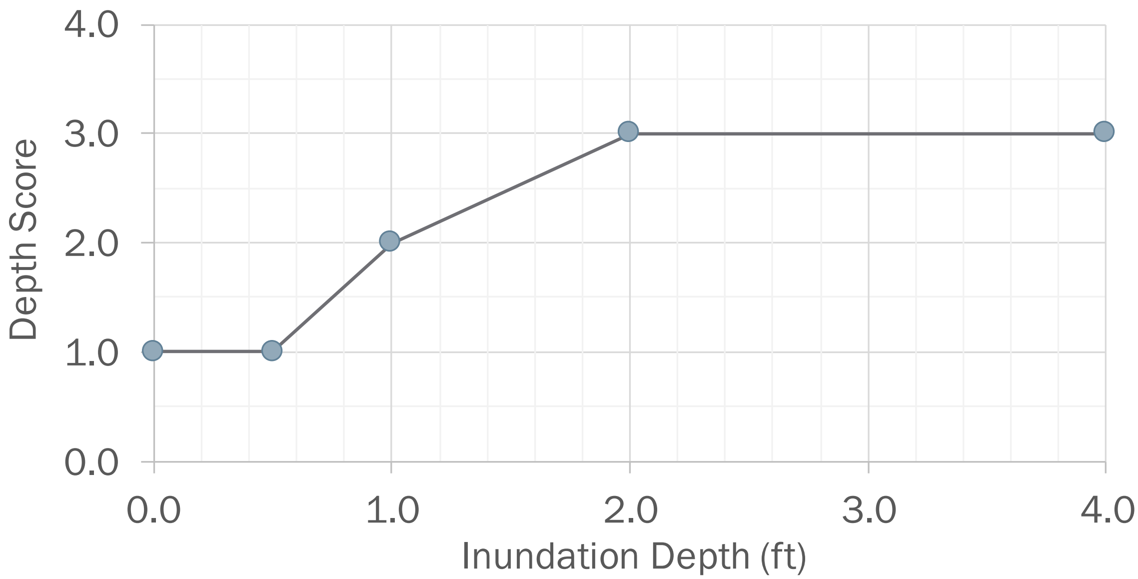


Figure 4-1. Depth component of the consequence score, by estimated depth

- **Confidence.** As discussed in Section 3, each creek has at least two estimates of the flood inundation extent. Anywhere the datasets overlap, there is higher confidence in the mapped inundation. Each single estimate differs in quality. Thornton Creek's Preliminary FIRM and Longfellow Creek's draft flood study mapped inundation were considered highest quality since they were based on detailed modeling. Also, anywhere within the mapped inundation that is based on the extrapolated 25-year SWMM results is also considered higher confidence.The number and quality of the datasets that indicate a given cell will be inundated was used to assign a confidence score (see Table 4-1). Any inundation location included based on only one dataset was given a confidence score of 0.

Table 4-1. Confidence Scores for Combined Data Sources

Data sources	Thornton Creek	Longfellow Creek	Piper's Creek	Fauntleroy Creek	Taylor Creek
All data sources	0.25	0.25	0.25	0.25	0.25
Any two data sources	0.1	0.1	0.1	same as all	same as all
At least one of the following: • SWMM 25-year, 24-hour • draft flood study • Preliminary FIRM	0.25	0.25	NA	NA	NA

- **High-use areas.** SPU provided the Consultant with geospatial data representing areas likely to have high pedestrian travel relative to other areas of the city. The data consisted of polygons representing areas with high pedestrian usage and polylines representing Neighborhood Greenways. The Consultant converted the latter to polygons based on the width of the right-of-way (ROW) and then merged them with the high pedestrian usage areas to create a single high-use areas dataset. A binary grid was developed by giving grid cells falling within the mapped high-use areas a value of one (1) and all other cells were given a value of zero (0). Spatially distributed scores were then calculated by multiplying the binary grid by a value of 0.5, assigning high-use areas a consequence score of **0.5**.

- **Critical facilities.** SPU developed geospatial point locations representing critical facilities. The Consultant downloaded polygons comprising King County's parcel data (King County Assessor 2018). Parcel polygon features containing one or more critical facility data points were selected. A binary grid was developed by giving grid cells where the centroid falls within the selected parcel areas a value of 1 and all other cells were given a value of 0. Spatially distributed scores were then calculated by multiplying the binary grid by a value of 1.25, assigning critical facilities a consequence score of **1.25**.
- **Major transportation routes.** SPU provided the Consultant with geospatial polylines representing snow and ice routes for Seattle Department of Transportation, which are indicative of the major transportation routes within the city. In addition, the Consultant selected lines associated with freeways (e.g., Interstate 5, Interstate 90, and State Route 520) from the City's streets geodatabase to include. All polylines were converted to polygons using the ROW width. A binary grid was developed by giving grid cells falling within the resulting polygons a value of 1 and all other cells were given a value of 0. Spatially distributed scores were then calculated by multiplying the binary grid by a value of 1.25, assigning major transportation routes a consequence score of **1.25**. There were six locations within the routes mapped as bridges. For the four bridges within the inundation extent, the estimated water depth was compared to the bridge height. Three bridges (West Seattle Bridge [Longfellow Creek], and 15th Ave NE and NE 110th St [both Thornton Creek]) were found to be high enough to not be impacted and were not given the major transportation route score.

Table 4-2 summarizes the component scores used to calculate combined consequence scores.

Table 4-2. Summary of Components of Consequence Score

Component	Score
Confidence	0.1-0.25
High-use area	0.50
Critical facility	1.25
Major transportation route	1.25

Parcel data (used to map critical facilities) do not overlap with ROW areas (used to map major transportation routes); therefore, a maximum score between critical facilities and major transportation routes is 1.25. Descriptions of the data provided by SPU are provided in Appendix C.

The Consultant used the citywide geospatial grids of the component scores described above to perform geospatial analyses (i.e., raster math) to calculate a citywide grid representing the consequence score. The consequence score varies from 0 to 5, representing an area (a) with an inundation depth of at least 3 feet, (b) in high confidence area (Table 4-1), (b) on a parcel with a critical facility or within the ROW of a major transportation route and (d) within a high-use area.

4.2 Likelihood Score

The risk associated with a creek flooding event increases with the probability, or likelihood, of occurrence. Only two recurrence intervals were analyzed: the 100 year and the 25 year. Recurrence interval (also referred to as return period or probability of exceedance) is defined as the probability of occurrence of a storm with associated rainfall characteristics such as peak intensity (inches/hour) or amount of rainfall (inches) over a defined duration (hours). For example, a 5-year, 24-hour recurrence interval with associated rainfall of 2.6 inches would mean that the probability of a storm generating 2.6 inches of rainfall over a consecutive duration of 24 hours is 1 in 5 or 20%. The annual recurrence interval is the reciprocal of the annual exceedance probability; thus, a 100-year storm is more likely than a 1,000-year storm.

The effective FIRM, the Preliminary FIRM, the draft flood study, and extreme storms data are all estimates of the 100-year flood inundation extent. The SWMM extrapolations were completed for a 100-year design storm event and – for Thornton and Longfellow creeks only – a 25-year design storm event. Table 4-3 lists likelihood scores for both recurrence intervals.

Since Thornton and Longfellow creeks are the only creeks with the mapped inundation from the 25-year SWMM model extrapolation (10 percent and 35 percent of inundation extent, respectively), there will likely be higher risk scores for these creeks.

Table 4-3. Likelihood Scores for Creek Flooding Risk Mapping

Average recurrence interval	Likelihood score
25-year SWMM Model extrapolation	5
Any 100-year flood inundation extent	3

4.3 Equity Score

An equity score is included to acknowledge that areas of racial and socioeconomic disparity are at a relative disadvantage to recover from a major flooding event. The City's Office of Planning and Community Development (OPCD) created a Racial and Social Equity Composite Index and associated geospatial mapping for all City departments to use, which has polygons representing 136 census tracts throughout the city. When developing these data, OPCD assigned an index to tracts based on racial diversity, demographics, health outcomes, and socioeconomic factors provided by the U.S. Census Bureau, American Community Survey, Centers for Disease Control and Prevention, and Washington State public health agencies. The range of indices was divided into five equity categories that reflect relative levels of disadvantage. For the DSA, the tracts with the highest level of disadvantage were assigned a score of 5. The tracts with the lowest level of disadvantage were assigned a score of 1. Table 4-4 provides the equity score for each level of disadvantage.

Table 4-4. Equity Scores for the DSA

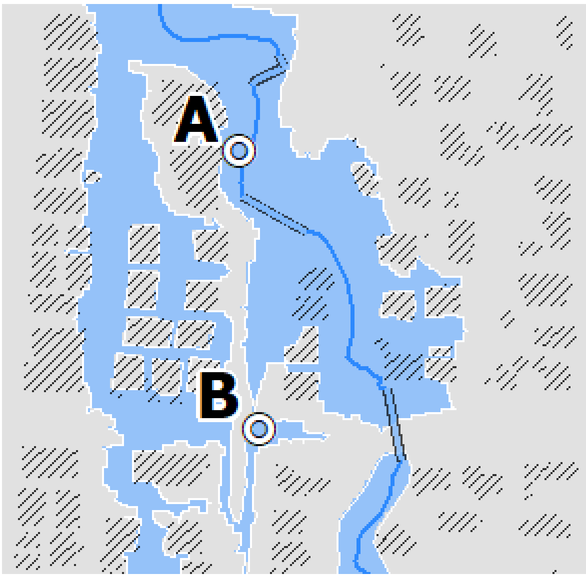
Level of disadvantage	Equity score
Highest	**5**
Second highest	**4**
Middle	**3**
Second lowest	**2**
Lowest	**1**

When the risk score method was developed for the wastewater system capacity evaluation completed as part of the Wastewater System Analysis (WWSA), the equity score could have been incorporated into the consequence criteria. SPU, however, decided to separate it out so that it could have greater influence on the risk score. SPU adopted the same risk score method for the DSA.

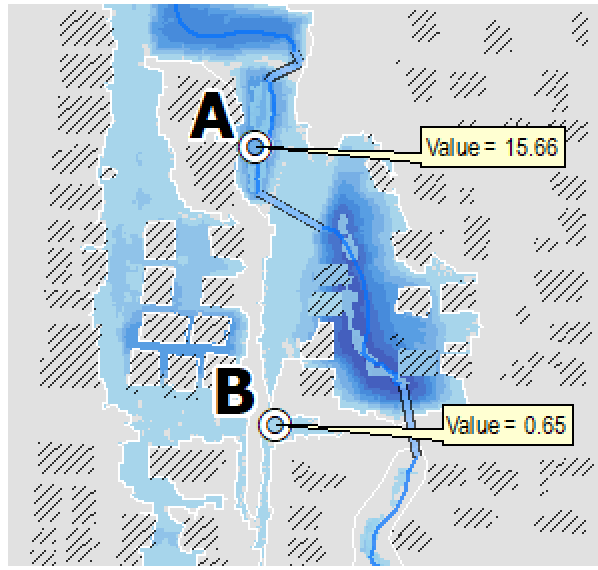
4.4 Example risk score calculations

Figure 4-2 shows two grid cell locations, ***A*** and ***B***, with risk scores of 22.8 and 11.2, respectively. The figure and description below explain how these scores were developed.

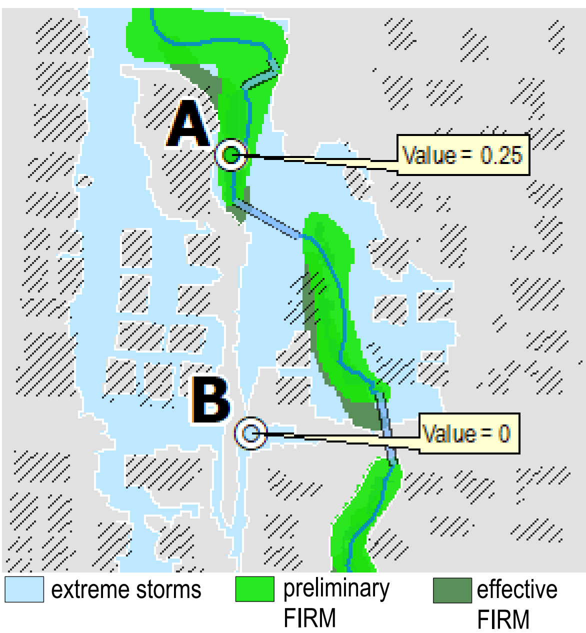
- Flooding at location ***A*** is deeper than at location ***B***, resulting in greater depth scores.
- Location ***A*** was identified through the overlap of multiple data sets and thus received a higher score than location ***B*** which was identified from only one data set.
- Both locations are in a high-use area, location ***B***, however, receives an additional score for being located within a major transportation route.
- Location ***A*** received a higher likelihood score since it was determined to inundate when extrapolating results from a 25-year design storm event, while Location ***B*** was based on an inundation extent estimated from the 100-year extreme storm event.
- Location ***A*** receives a higher equity score than location ***B***.



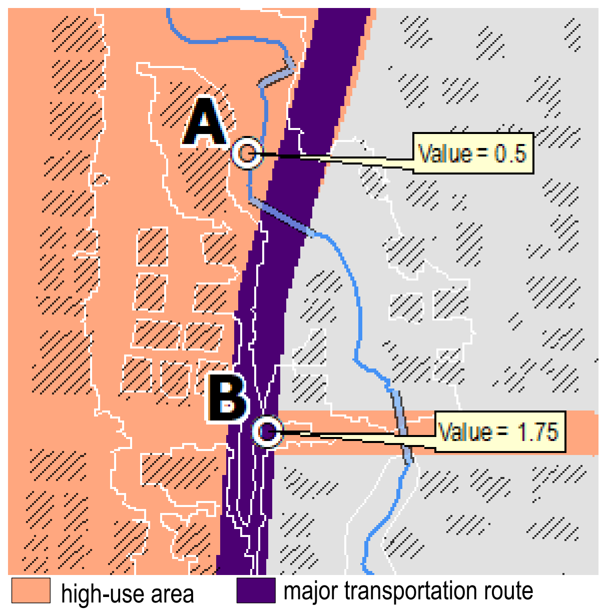
(a) Flooding inundation extents from various sources



(b) Flooding depths from sources used

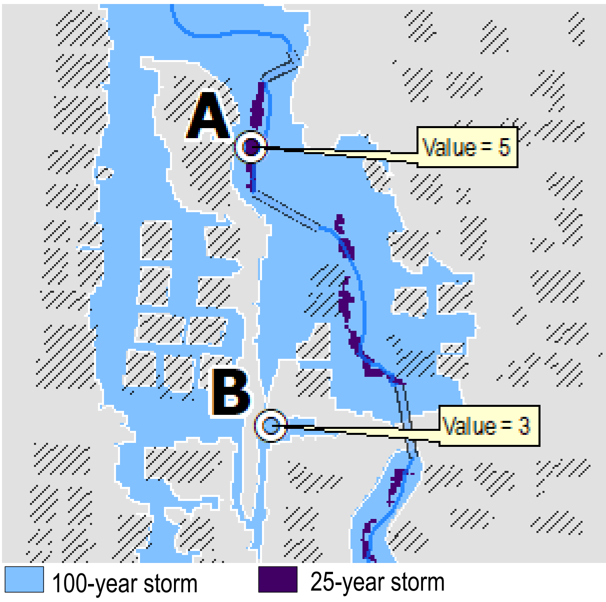


(c) Confidence score based on number and type of overlapping data

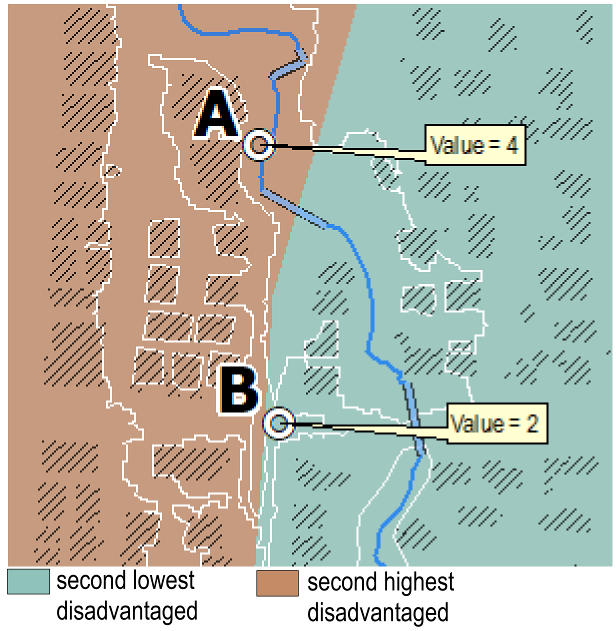


(d) Location scores with major transportation route and high-use areas; no critical facilities within this example area

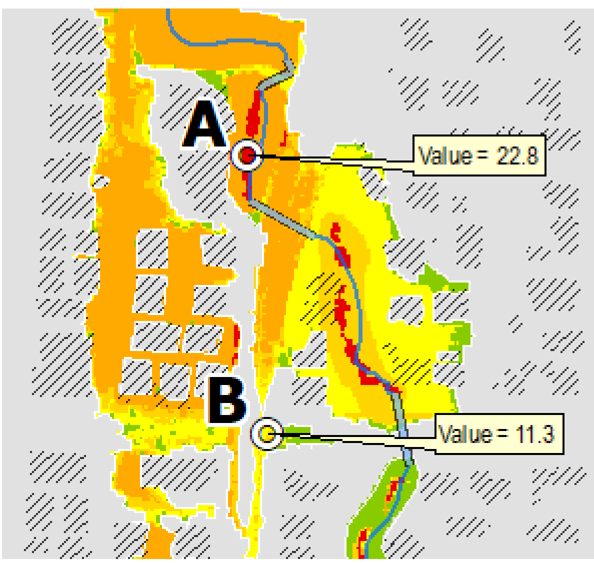
Figure 4-2. Example risk score calculations



(e) Likelihood score



(f) Equity scores



(g) Mapped risk scores for example area

Parameter/score	Location A	Location B
Depth (feet)	15.66	0.65
Depth score	3	1.3
Confidence score	0.25	0
Location score	0.5	1.75
Consequence score *(depth + confidence + location)*	3.75	3.05
Likelihood score	5	3
Equity score	4	2
Risk score	**22.8**	**11.2**

(h) Risk score calculations for example locations A and B

Figure 4-2. Example risk score calculations (cont'd)

5. Results Summary

Creeks within Seattle provide stormwater management opportunities as well as community benefits. It is important to understand their response to precipitation and potential for flood inundation in surrounding areas. SPU has taken a comprehensive approach to assess existing data to produce risk maps for major creeks within city limits.

5.1 Risk Scoring Results

Risk scoring was completed for each of the creeks analyzed. Flood inundation extent mapping resulted in a total creek flooding risk area of approximately 446 acres. The Consultant applied the risk scoring methods described in Section 4 to the mapped inundation areas to calculate and map the variable risk score at a 4-ft grid resolution.

Once the scoring was established, the Consultant calculated breaks to map five nearly equal (by area) categories of relative risk: low, medium low, medium, high, and critical. (The distribution of the data precluded equal area breaks.) Table 5-1 shows the risk score ranges for each risk category.

Table 5-1. Creeks Risk Categories and Scores

Relative risk category	Risk score range
Low	4.0 – 8.75
Medium low	8.75 – 11.3
Medium	11.3 – 13
High	13 – 17.25
Critical	17.25 – 29

Figure 5-1 show the distribution of inundation area by relative risk category for each of the creeks.

Table 5-2. Inundation Area (acres) by Relative Risk Category per Creek

Relative risk category	Fauntleroy Creek	Longfellow Creek	Taylor Creek	Piper's Creek	Thornton Creek	Total
Low	1.3	26.1	0.6	24.2	36.9	89.2
Medium low	2.0	18.9	2.0	4.7	62.2	89.9
Medium	0.6	41.3	1.6	3.8	46.9	94.2
High	0.1	8.0	3.4	6.2	79.8	97.5
Critical	0	9.4	0	0	65.7	75.1
Total area per creek	**4.0**	**103.7**	**7.6**	**38.9**	**291.5**	**445.9**
Basin area	149	1,509	628	1,572	7,019	10,877
Risk area percent of basin area	**3%**	**7%**	**1%**	**2%**	**4%**	**4%**

Longfellow Creek and Thornton Creek basins showed both the largest total and percent inundation area as well as the only basins with mapped areas that contain a "critical" relative risk area. Qualitative results discussion for each of the creek basins is in Section 5.2.

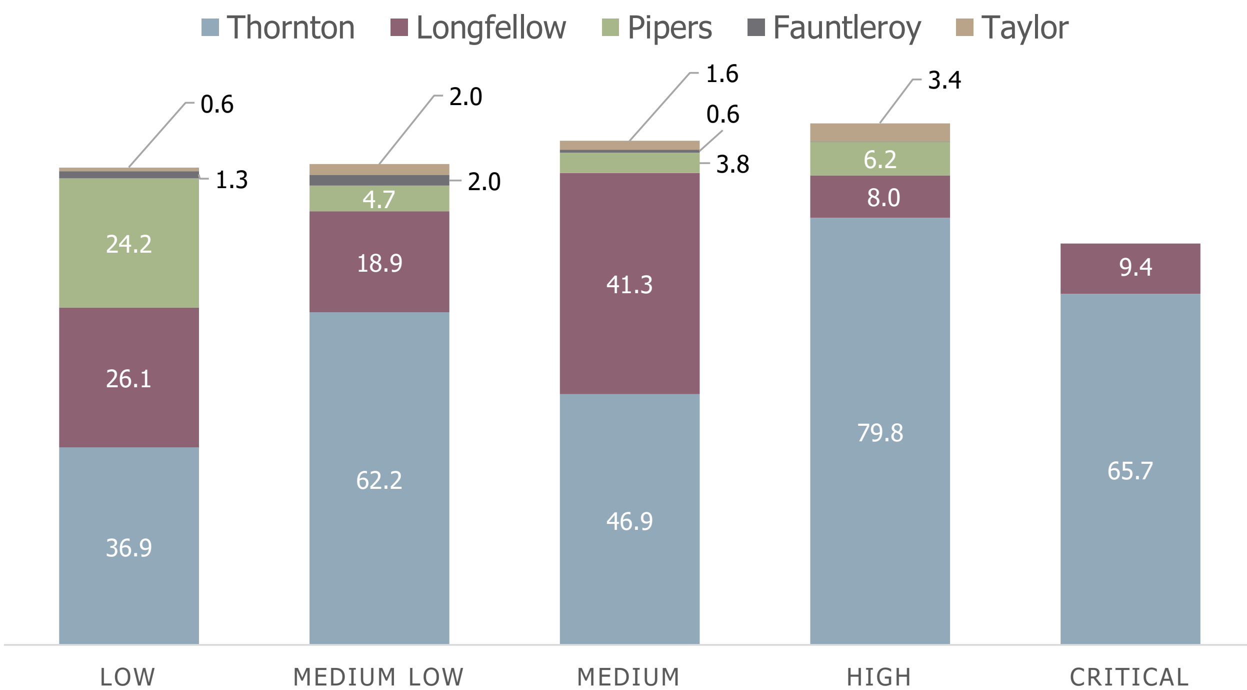


Figure 5-1: Inundation Area by Risk Category per Creek

5.2 Risk Area Discussion

This section provides a brief discussion of the risk mapping in each basin. Risk area maps for each basin are provided in Appendix D. SPU's Urban Watercourses data are also shown on each map; however, these data may not align with the risk area in all locations. Inundation mapping analyses performed for this study relied on a land surface DEM, but the Urban Watercourses shown on the maps do not always follow the lowest elevations reflected in the DEM.

5.2.1 Fauntleroy Creek

Much of Fauntleroy Creek's risk area is along the mainstem of the creek, with minimal locations included in the risk area along its tributaries. As the main stem flows via culverts under three roadways (California Ave SW, 45th Ave SW, Fauntleroy Way SW), the risk area spreads laterally behind the culverts. This is seen in the extreme storm analysis results. For the DEM-based surface flow modeling completed for extreme storms analysis, culverts are not included, which can lead to simulated inundation upstream of roadway embankments. This inundation could represents risks caused by blocked or damaged culverts. The higher ("high" and "medium") risks identified within the area are attributed to deeper estimated depths within the ravines and a high use-area east of 45th Ave SW.

5.2.2 Longfellow Creek

The risk area for Longfellow Creek starts narrow at the headwaters and becomes wider, with the potential to extend beyond the extent of the creek as it flows downstream. Near the mouth of the creek, the risk area expands given the topography of the land and the results of the extreme storms analysis. Longfellow Creek flows through an 8-foot diameter culvert in this location and there are no known incidents of flooding related to this culvert. This inundation could represent potential surface flooding not related to the creek or flooding if the culvert were blocked or damaged. The mapped "critical" risks can be attributed to the inundation extent estimated from the SWMM model results for the 25-year design storm event (resulting in a higher likelihood score) as well as an overlap with a high-use area along 26th Ave SW.

The analysis was limited to the extent of the SWMM model basin and creek representation as seen with the abrupt inundation extent at the upstream end, and the inundation extent matching the basin boundary at the downstream end.

5.2.3 Taylor Creek

The Taylor Creek risk area includes locations along the mainstem as well as the West and East Fork. There are patches of wider inundation along all three, with the largest area downstream of the culvert under Holyoke Place S. The inundation area did not overlap with any high-use areas nor critical facilities and the very small overlap with a major transportation route did not have much impact on the risk area. The "high" risks are attributed to deeper estimated depths within portions of the creek (East Fork) or topographic depressions (mainstem upstream of culvert under Rainier Ave S).

The analysis was completed for creek areas within the city. Risk area likely exists on portions of the creek outside the city, particularly on the East Fork where the inundation extent terminates with a straight edge along the city boundary. The risk area along Lake Washington is limited to the SWMM boundary extent. This area is relatively flat and risk area may extend beyond what is mapped.

5.2.4 Piper's Creek

The majority of the risk area for Piper's Creek is along the mainstem. The risk area here is wide, and not always aligning with the mapped creek as this is the inundation extent in the FIRM data. It is mapped as low risk since there are not overlapping data and the FIRM data were given the lowest depth score. These areas also did not overlap with a high-use area, critical facility, or major transportation route. The "high" risks along the mainstem, north of NW 105th St, can be attributed to overlapping data from several sources and deeper depth estimates The "high" risks to the north of Holman Road NW are due to the presence of a major transportation route. The tributaries to the main stem show some risk area generally contained near the creek. Risk area that is not near the creek, such as the "medium low" risk area south of the creek, is from the extreme storms analysis and may be more representative of a surface flooding risk and not a creek flooding risk.

5.2.5 Thornton Creek

Thornton Creek is the largest creek basin by total area and total risk area size, although not the largest by percent of basin area. The four largest inundation extents consist of Jackson Park Golf Course on the North Branch, near the headwaters of the South Branch, the larger Meadowbrook Pond area and the mouth of the mainstem. The extent of these are largely determined from the extreme storm analysis results. The locations on the North and South branches could represent blocked or damaged culverts, both along Roosevelt Way NE. The area around Meadowbrook Pond and the mouth represent flatter areas.

The mapped "critical" risk area can be attributed to the inundation extent estimated from the SWMM model results for the 25-year design storm event and Preliminary FIRM (resulting in a higher likelihood score), as well as an overlap with a high-use areas.

The analysis was completed for creek areas within the city. Inundation due to creek flooding likely exists on portions of the creek (North Branch and Littles Creek) outside the city, but these areas are not included in this analysis. Also, along Littles Creek, the SWMM model results could not be successfully extrapolated due to the topography and were excluded. (See Appendix A for the creek sections for which SWMM results were excluded.)

6. Limitations

The creek inundation maps and risk scoring data have been developed for informational purposes and to support the development of the Shape Our Water Plan for SPU DWW. These data identify areas of the city that may be at higher risk during inundation due to creek flooding. Use and interpretation of these results requires an understanding of the assumptions and limitations associated with the analysis. As planning progresses and focuses more on specific areas of interest, creek flooding assessments may need to be more advanced and refined. The following limitations have been identified for consideration:

- Existing SWMM model results predict the 1D flow of water through a given system. Extrapolation of these results to a 2D representation of flood depth and extent has limitations given the 1D input data's intended use. The SWMM model results represent a collection of nodes and links. The SWMM models were developed with input sources that may differ from other layers used in this analysis. For example, a SWMM node that represents a point in the channel may not directly align with the spatial location of the lowest geographic location on the land surface DEM. The modeled elevation of the SWMM node may also represent a point upstream or downstream of its mapped location relative to the elevation that it represents. To remove part of this uncertainty, predicted flood depth at each node was added to DEM elevation rather than using predicted node water level directly. This was done to remove the possibility of the SWMM node water level being lower than the land surface elevation. This provided a more conservative estimate of surface water depth, but may over-estimate depth and extent if the modeled channel invert is considerably lower than the land surface DEM.
- A consistent approach was applied to all SWMM models to extrapolate water depth to provide a consistent framework for risk scoring. Certain models have higher resolution than others, and even resolution within models varies. For example, some stream channels were surveyed while others (Longfellow and Fauntleroy) were estimated from contour data; lower precision in modeled channel cross-section affects the accuracy of predicted flood depths, and in turn the reliability of the extrapolated flood inundation extent. In addition, there is wide variation both within and across models in the distance between nodes. More widely spaced nodes (longer creek segments) yield extrapolated flood inundation extents with lower precision (see Appendix A).
- Extrapolation of 1D to 2D results does not account for conservation of volume. Whereas the 1D model conserves the volume of water in the system, extrapolating this depth can lead to over-prediction of flood inundation extent for a given depth. For example, shallow flat areas drained by a deep, but narrow channel, that is represented in the SWMM model but not the land surface DEM, could show much larger spread of water based on a constant extrapolated water surface elevation that may not be consistent with the volume of water available in the 1D flow of water calculated in the SWMM model. This was found to occur on Littles Creek (see Section 5.2.5).
- The extreme storms results that were used to inform depth and inundation extents are representative of surface flow and utilize the land surface DEM to move water across the surface. Culverts and other below ground hydraulics are not represented, and topographic land barriers can trap water and create artificial ponds; when in reality, flood waters would be conveyed by sub-surface conveyance. This can lead to an over-estimate of depth in creek sections adjacent to raised roadways, bridges and other infrastructure (see Section 5.2.1).

- Model hydraulics and creek cross-sections are based on the best available information at the time of model development and update (Table 2-2). As additional information becomes available, revisions to SWMM models (e.g. larger culvert sizes could remove modeled hydraulic restrictions that lead to higher node depths, which are misrepresented further by extrapolation) could be made.
- The flood inundation extent draws on multiple sources of information (SWMM, extreme storms, FIRM) that were developed from a variety of input sources. All available input sources were used to provide a larger inundation extent to be used in the risk map. Some of these sources (see Section 5.2.4, for example) offer markedly different estimates of the depth or extent of flooding. While the risk scoring method attempted to address the different sources, the risk area may be overestimated.
- The method used to approximate water surface elevation from SWMM model results is based on the spatial resolution of transects applied and causes inherent smoothing of water surface profiles based on distance of points. Using depth as a proxy to estimate water surface elevation may create water surface profiles that are not entirely indicative of how water flows through a given channel or floodplain. Point resolution and sample spacing impact how the water surface elevation is interpolated. This was tested through iterations early on in the process and checked at the end to ensure water surface elevations decreased while moving downstream to ensure that SWMM model depth to water surface extrapolation did not create unintended consequences where the water surface level was higher downstream.
- The DSA SWMM models for the five creek basins have been updated at different times to achieve different project objectives. Information on these models and references to their development can be found in an appendix to the DSA Drainage System Capacity Evaluation (Brown and Caldwell 2020).
- Equity score has less influence, when compared to capacity analyses completed for the WWSA and DSA, on the risk score. When the risk score method was developed for the WWSA, SPU decided to separate it out from the consequence component of the score, so that it could have greater influence on the risk score. For the creek flooding risk map, however, it has less influence on the final score when compared to the individual scores of the few consequence score components. For example, for highest likelihood events, a critical facility contributes more than the equity score, to the risk score.

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Quantum Spatial (2016). Digital Elevation Model developed from Light Detection and Ranging (LiDAR) data provided by King County and Puget Sound LiDAR Consortium.

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Appendix A: SWMM Model Representation Maps

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Seattle Public Utilities

Drainage System Analysis

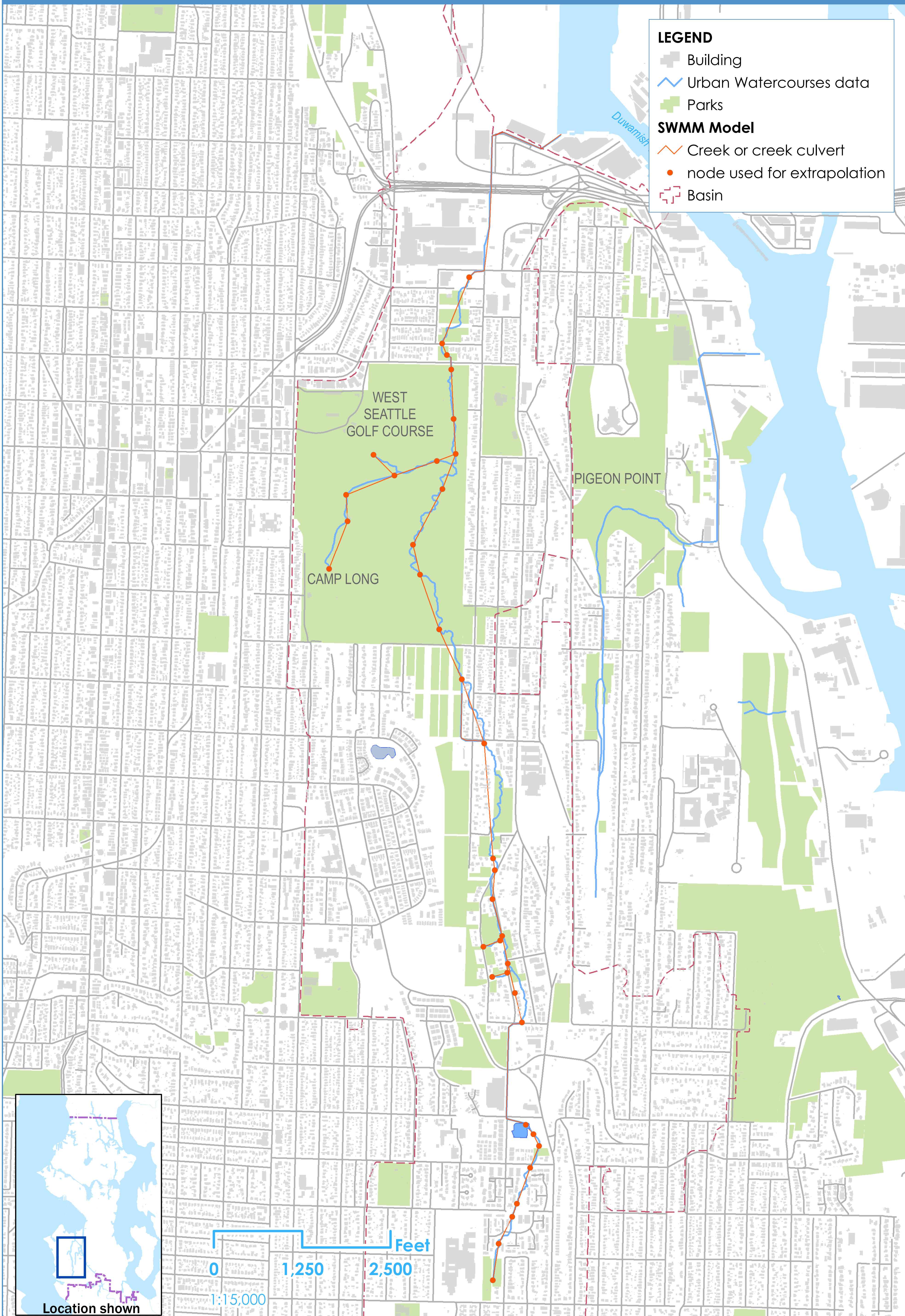
Figure A-1. SWMM Model Representation for Fauntleroy Creek

Author: DSA Team Date: 9/23/2020 File Path: X:\Separated Systems\Business_Areas\Planning\DSA\mxd\DSA_T2_Creeks_AppA_SWMM.mxd

Seattle Public Utilities

Drainage System Analysis

Figure A-2. SWMM Model Representation for Longfellow Creek



Author: DSA Team Date: 9/23/2020 File Path: X:\Separated Systems\Business_Areas\Planning\DSA\mxd\DSA_T2_Creeks_AppA_SWMM.mxd

Seattle Public Utilities

Drainage System Analysis

Figure A-3. SWMM Model Representation for Taylor Creek

Author: DSA Team Date: 9/23/2020 File Path: X:\Separated Systems\Business_Areas\Planning\DSA\mxd\DSA_T2_Creeks_AppA_SWMM.mxd

Seattle Public Utilities

Drainage System Analysis

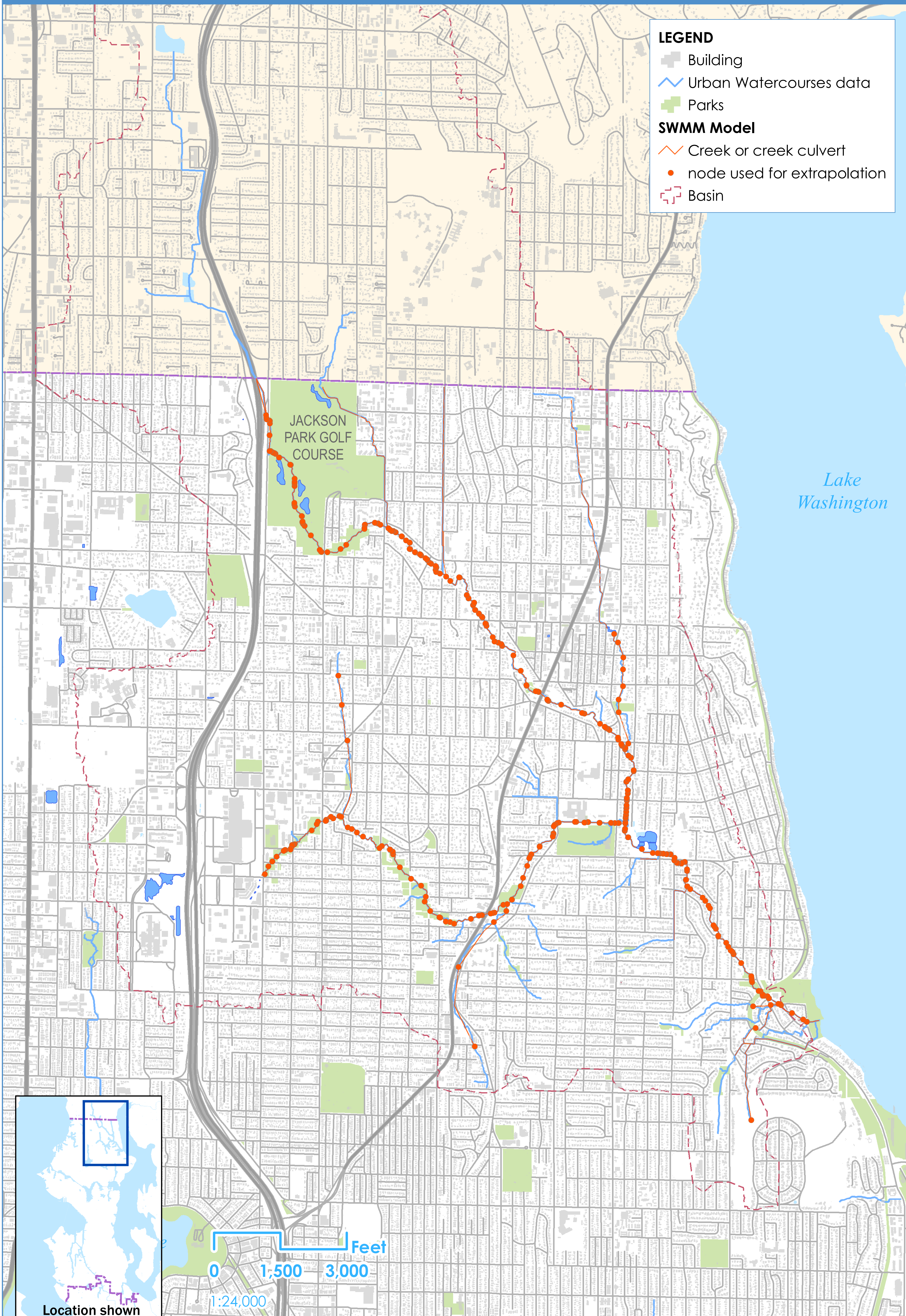
Figure A-4. SWMM Model Representation for Piper's Creek

Author: DSA Team Date: 9/23/2020 File Path: X:\Separated Systems\Business_Areas\Planning\DSA\mxd\DSA_T2_Creeks_AppA_SWMM.mxd

Seattle Public Utilities

Drainage System Analysis

Figure A-5. SWMM Model Representation for Thornton Creek



Author: DSA Team Date: 9/23/2020 File Path: X:\Separated Systems\Business_Areas\Planning\DSA\mxd\DSA_T2_Creeks_AppA_SWMM.mxd

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Appendix B: GIS Processes

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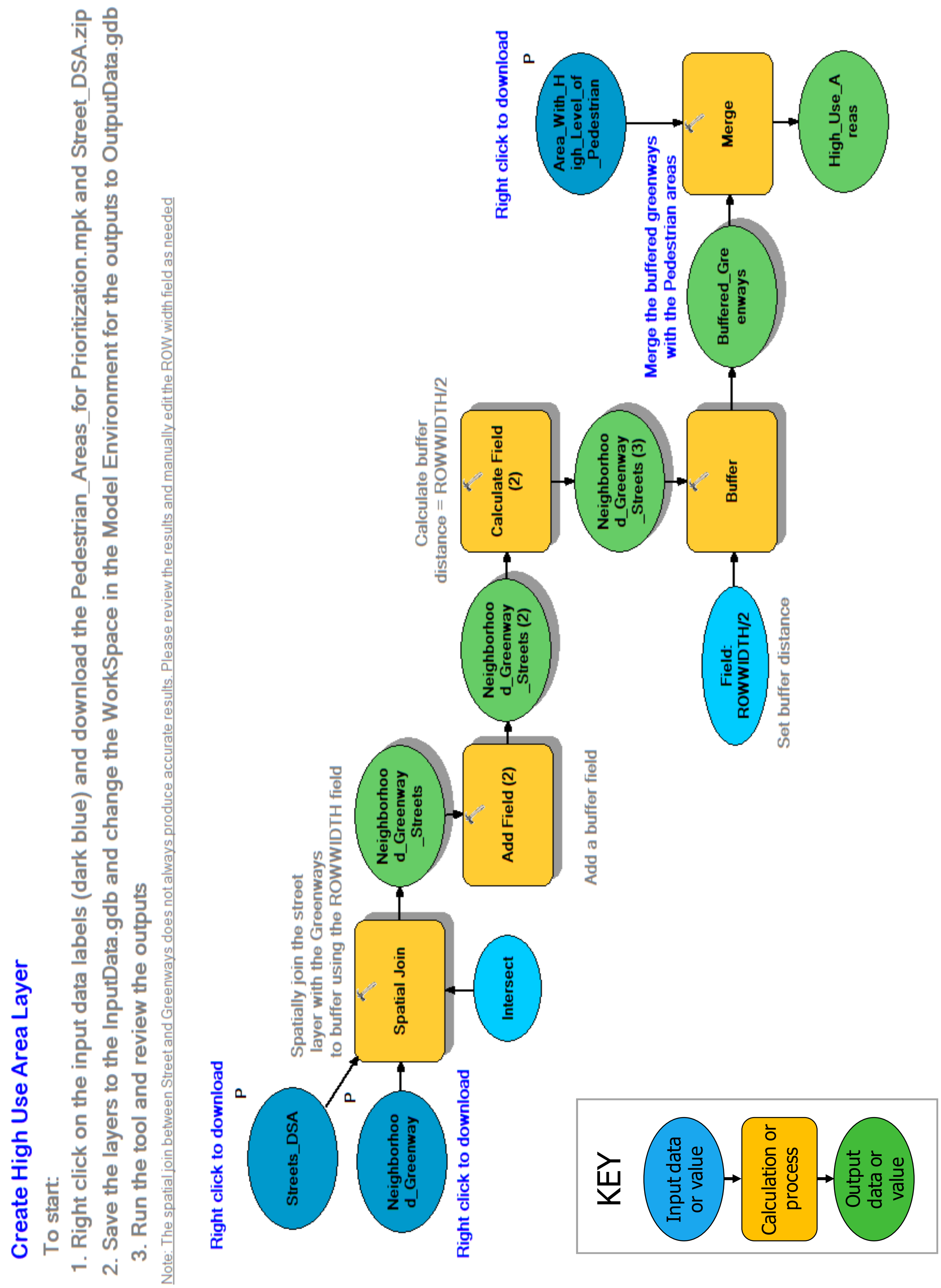

Figure B-1. ArcGIS model builder for developing high-use area raster

Create Critical Facility polygon Layer

To start:

1. Right click on the input data labels (dark blue) and download the data
2. Unzip the parcel layer and save the two layers into the InpurData.gdb dataset
3. Change the WorkSpace in the Model Environment to set the outputs to OutputData.gdb
4. Run the tool and review the outputs

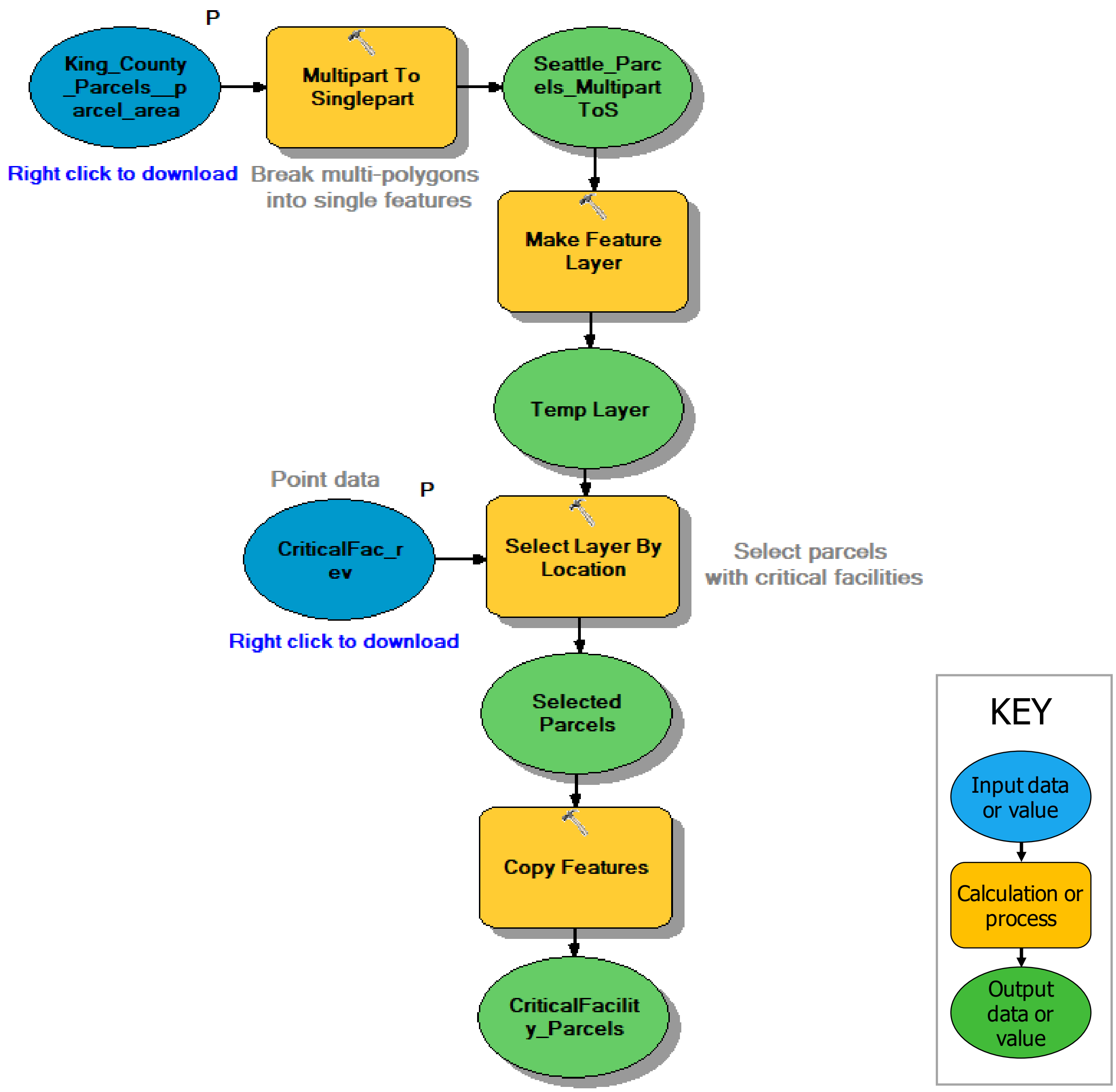

Figure B-2. ArcGIS model builder for developing critical facility area raster

Create Buffered Streets Layer

1. Right click on the input data labels (dark blue) and download the Street_DSA.zip
2. Save the layers to the InputData.gdb
3. change the WorkSpace in the Model Environment for the outputs to OutputData.gdb
4. Run the tool and review the outputs

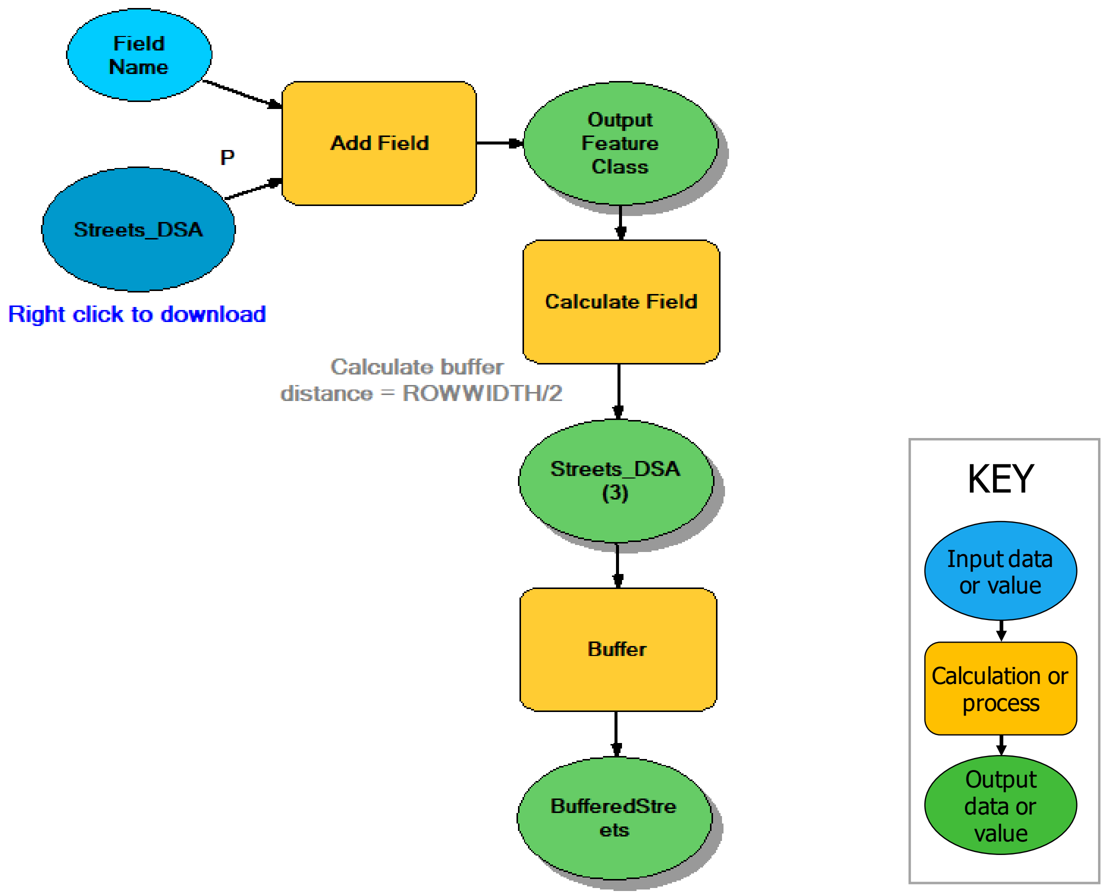

Figure B-3. ArcGIS model builder of street buffers for major transportation routes raster

Create Equity Layer:

To start:

1. Right click on the input data labels (dark blue) and download Racial and Social Equity Composite Index - 2018.zip
2. Unzip the shapefile and add to the InputData.gdb database
3. If necessary, change the WorkSpace in the Model Environment to set the outputs to OutputData.gdb
4. Run the tool and review the outputs

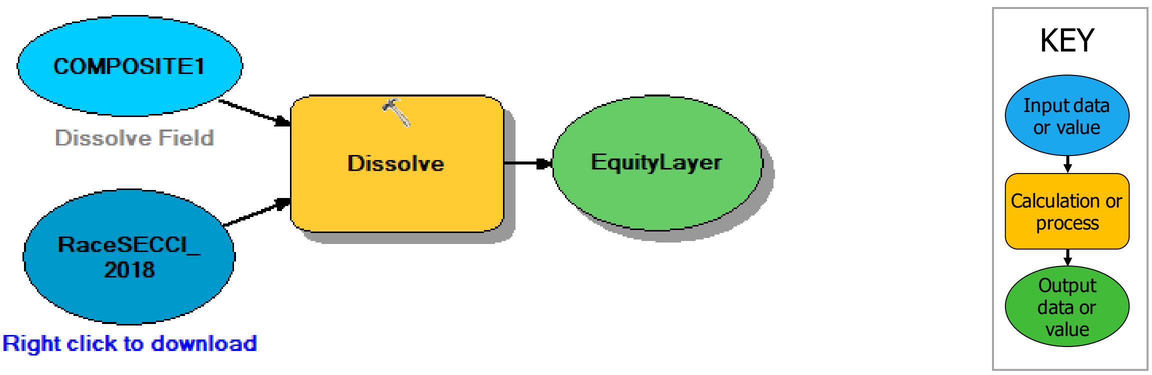

Figure B-4. ArcGIS model builder for developing equity raster

Appendix C: GIS Data Sources

Technical Memorandum: GIS data for Risk Mapping and Prioritization for the System Analyses Projects

July 17, 2020

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Seattle Public Utilities

Memorandum

Date: 7/17/20

To: Project File

From: Colleen O'Brien

Re: GIS data for Risk Mapping and Prioritization for the System Analyses Projects

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This memorandum describes the GIS data used in developing risk scores for the Wastewater System Analysis (WWSA) and Drainage System Analysis (DSA), particularly the DSA Sea Level Rise risk map.

For each data set it includes:

- For the source data, summarized in Table 1:
  - Description
  - Source and date
  - Storage location
  - What data set it became part of or was used to create (process data) for an analysis or map
- For processed data, summarized in Table 2:
  - Description, including how it was modified from the source data
  - Storage location (includes network drive location and may include a SharePoint location)
  - Date of the file
  - Which analysis it was used in

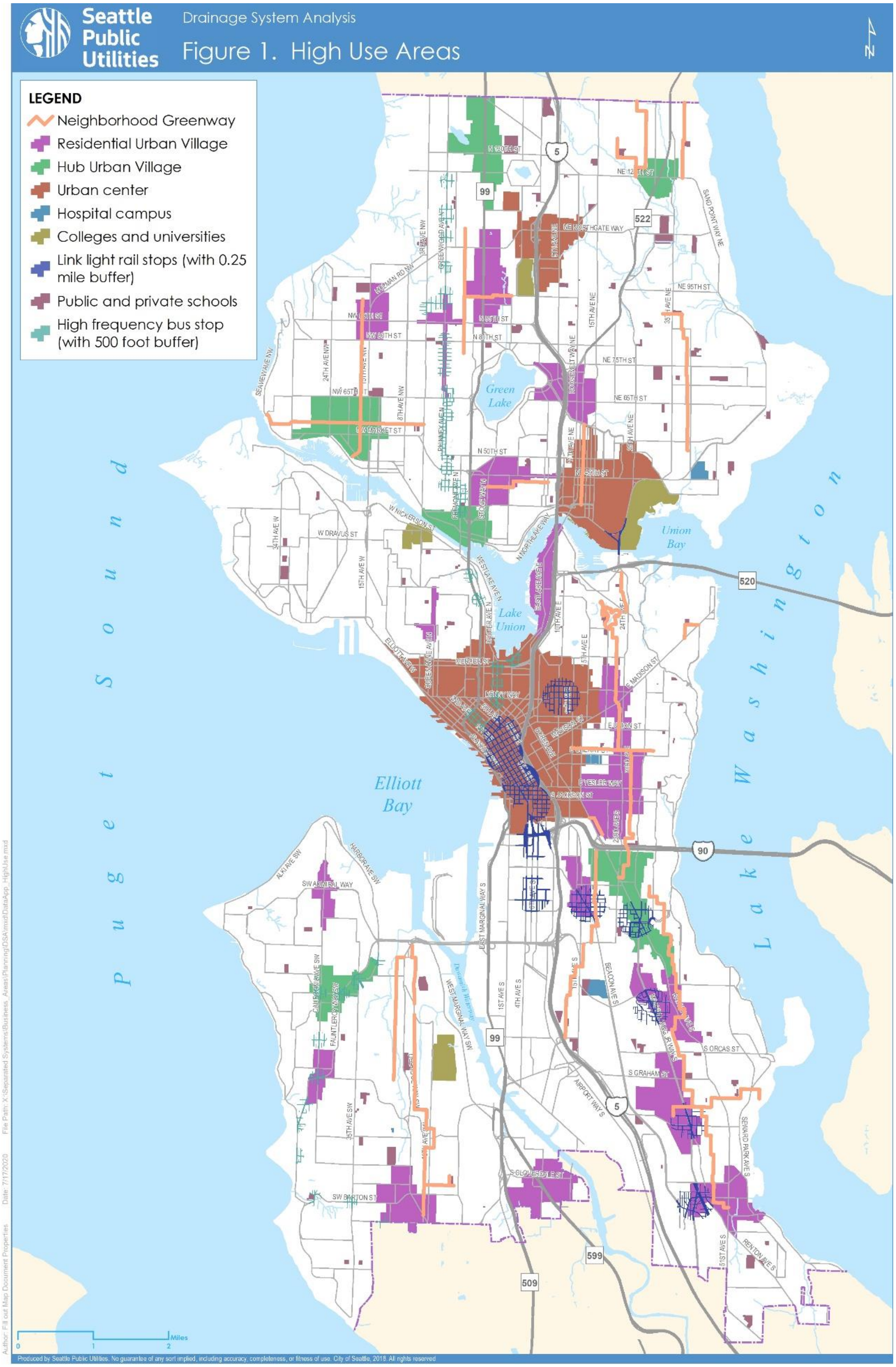
Table 1. GIS Source Data used in Risk Mapping and Prioritization for the System Analyses Projects

Name	Description	Source	Date	Storage Location	Name of Analysis Data Set Used In
City of Seattle	Polygons of city limits, land, and water bodies. Does not extend far enough east to include Mercer Island or Bellevue landforms. This feature class reflects the visual interface between land and water based upon our 1993 ortho photos. It essentially follows the 8 foot contour line, except where the ortho offered further clarification. That 8 foot contour line matches closest to what NAVD88 shows as "mean high water" (see official definition below) at 7.97 feet. MEAN HIGH WATER (MHW): "A tidal datum. The average of all the high water heights observed over the National Tidal Datum Epoch. For stations with shorter series, simultaneous observational comparisons are made with a control tide station in order to derive the equivalent datum of the National Tidal Datum Epoch."	City	3/18/20 (downloaded from Seattle Tools)	*Seattle Tools*, Streets (CARTO.SHORE)	land area
Colleges and universities (Figure 1)	Boundaries of colleges and universities in the city of Seattle.	City	Sept 2018	*Seattle Tools*, Colleges and Universities (CARTO.COLLEGE)	high use area
Critical facilities (Figure 2)	Provide services and functions essential to a community, especially during and after a disaster.	OEM	10/8/2018 (received from OEM)	*X:\Separated Systems\Business_Areas\Planning\DSA\analysis\CriticalFacilities* Critical Facilities (OEM).txt	critical facilities
High frequency bus stops (Figure 1)	On-street location where transit vehicles stop inline to pick-up and discharge passengers.	KC Metro	Sept 2018	*Seattle Tools*, King County Metro Bus Stop, Active & In Service (KCGIS.TransitStop_point)	high use area
Hospital campuses (Figure 1)	Boundaries of licensed acute care hospitals and associated buildings.	City	Sept 2018	*Seattle Tools*, Hospitals (CARTO.HOSPITAL)	high use area
King County parcels	Tax parcels polygons in King County.	KC	1/14/2018 (downloaded from website)	*https://gis-kingcounty.opendata.arcgis.com/datasets/8058a0c540434dadbe3ea0ade6565143_439*	properties and critical facilities
Link light rail stops (Figure 1)	Contains the entire set of existing Central Link, University Link, and Airport Link light rail station points located in the City of Seattle from Northgate Mall to SeaTac Airport.	ST	Sept 2018	*Seattle Tools,* Sound Transit Link Light Rail Stations (CARTO.LinkStations)	high use area
Neighborhood Greenways (Figure 1)	Safer, calmer residential streets that can include: • easier crossings of busy streets with crosswalks, flashing beacons, or crossing signals • speed humps to calm traffic • stop signs for side streets crossing the greenway • signs and pavement markings to help people find their way • 20 mph speed limit signs	SDOT	Sept 2018	*P:\PrjMgmt\C316073 2018 Wastewater System Analysis\02-Plan Inputs\G-GIS\To Aqualyze* Prioritization-Layers.mpk	high use area
Public and private schools (Figure 1)	Parcels that contain kindergarten through 12th grade public and private schools approved through the Washington State Board of Education.	City	Sept 2018	*Seattle Tools*, Public School and Private School (CARTO.PRIV_SCH and CARTO.PUB_SCH)	high use area

Name	Description	Source	Date	Storage Location	Name of Analysis Data Set Used In
Racial and Social Equity Composite Index (Figure 3)	Census tract-based data that consists of a composite of the following sub-indices: • Race, English Language Learners, and Origin Index ranks census tracts by an index of three measures weighted as follows: (shares of population who are) - persons of color (weight: 1.0) - English language learners (weight: 0.5) - foreign born (weight: 0.5) • Socioeconomic Disadvantage Index ranks census tracts by an index of two equally weighted measures: (shares of population with) - income below 200 percent of poverty level - educational attainment less than a bachelor's degree • Health Disadvantage Index ranks census tracts by an index of seven equally weighted measures: - no leisure-time physical activity - diagnosed diabetes - obesity - mental health not good - asthma - low life expectancy at birth - disability	OPCD	2018 (DSA) 2017 (WWSA)	DSA *DWW GIS Library (DSA) on SharePoint* Racial and Social Equity Composite Index – 2018.zip (RaceSECCI_2018.shp) *X:\Separated Systems\Business_Areas\Planning\DSA\data\Impacts* RaceSECCI_2018.shp WWSA *P:\PrjMgmt\C316073 2018 Wastewater System Analysis\02-Plan Inputs\G-GIS\To Aqualyze* Prioritization-Layers.mpk	Racial and Social Equity Composite Index
Residential and Hub Urban Villages (Figure 1)	Areas in the city with residential development as well as a broad mix of uses with lower densities than urban centers. (See the Comprehensive Plan 20-year Growth Strategy, http://www.seattle.gov/Documents/Departments/OPCD/OngoingInitiatives/SeattlesComprehensivePlan/CouncilAdopted2016_CitywidePlanning.pdf)	OPCD	Sept 2018	*Seattle Tools*, Urban Centers, Villages, Manufacturing Industrial Centers (CITYPLAN.URBAN_VILLAGE_CENTER_MIC)	high use area
Snow and ice routes (Figure 4)	City of Seattle streets covered under SDOT's Winter Storm Response Plan, showing snow and ice removal routes.	SDOT	9/21/18 (downloaded from Seattle Tools)	*DWW GIS Library (DSA) on SharePoint* SDOT_snowice.zip (SDOT_snowice.shp) *X:\Separated Systems\Business_Areas\Planning\DSA\data\Impacts* SDOT_snowice.shp	major transportation routes and street type
Streets	The City's Street Network Database showing driveable public streets within the Seattle city limits.	SDOT	1/24/2020 (downloaded from Seattle Tools)	*Seattle Tools*, Streets (SDOT.STREETS)	streets

Name	Description	Source	Date	Storage Location	Name of Analysis Data Set Used In
Urban center (Figure 1)	Densest developed areas in the city with the widest range of land uses. (See the Comprehensive Plan 20-year Growth Strategy, http://www.seattle.gov/Documents/Departments/OPCD/OngoingInitiatives/SeattlesComprehensivePlan/CouncilAdopted2016_CitywidePlanning.pdf)	OPCD	Sept 2018	*Seattle Tools*, Urban Centers, Villages, Manufacturing Industrial Centers (CITYPLAN.URBAN_VILLAGE_CENTER_MIC)	high use area

OPCD = Office of Community Planning and Development
City = City of Seattle
ST = Sound Transit
KC = King County
SDOT = Seattle Department of Transportation
OEM = Office of Emergency Management
DWW GIS Library (DSA) on SharePoint = *https://seattlegov.sharepoint.com/:f:/r/sites/spu-D1/Planning/DWW%20GIS%20Library/DSA/Data/SPU?csf=1&web=1&e=UBk4k2*


Seattle Public Utilities
Drainage System Analysis
Figure 1. High Use Areas
LEGEND
Neighborhood Greenway
Residential Urban Village
Hub Urban Village
Urban center
Hospital campus
Colleges and universities
Link light rail stops (with 0.25 mile buffer)
Public and private schools
High frequency bus stop (with 500 foot buffer)
Puget Sound
Elliott Bay
Lake Washington
Lake Union
Green Lake
Union Bay
Miles
0
1
2

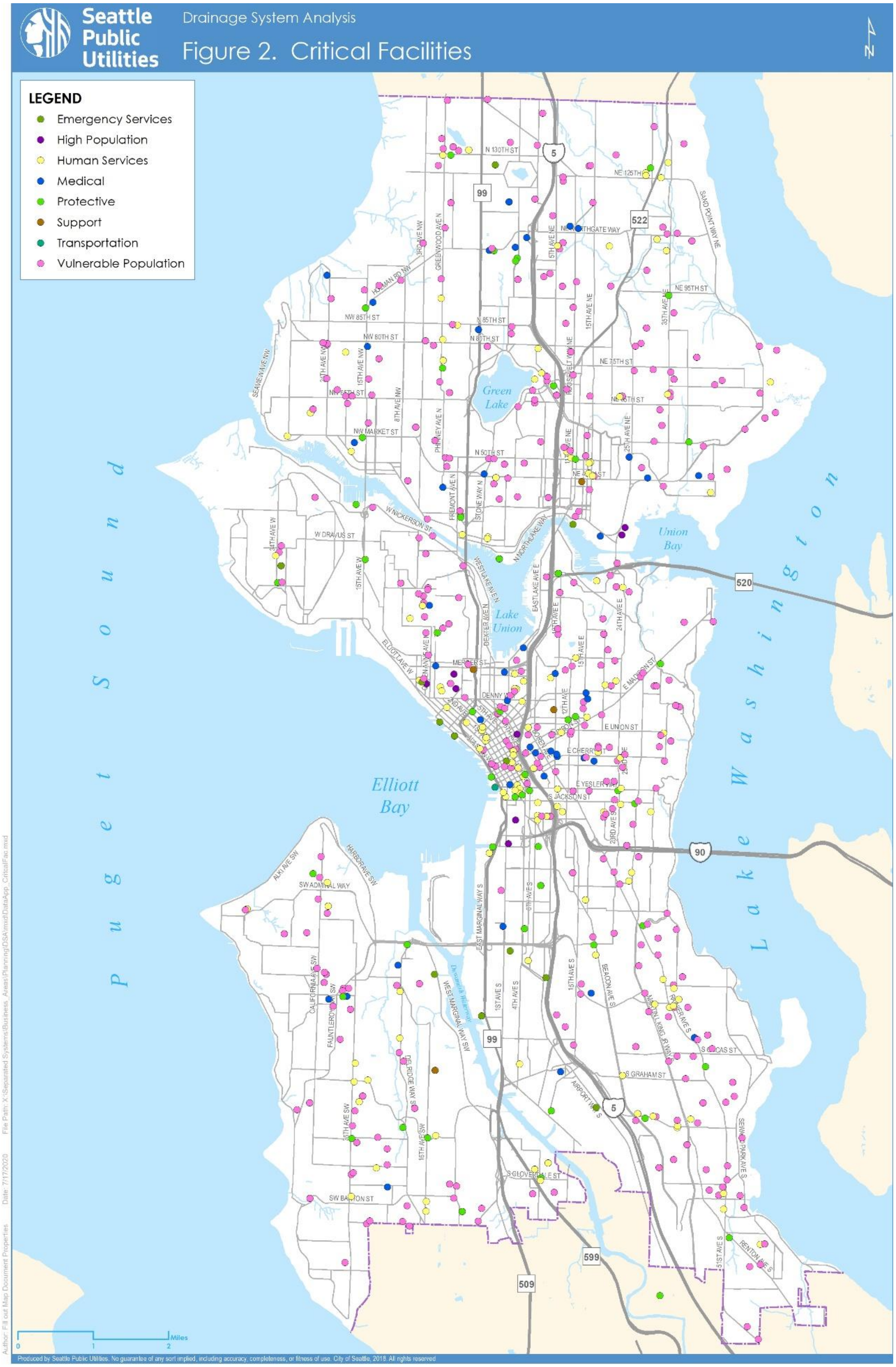

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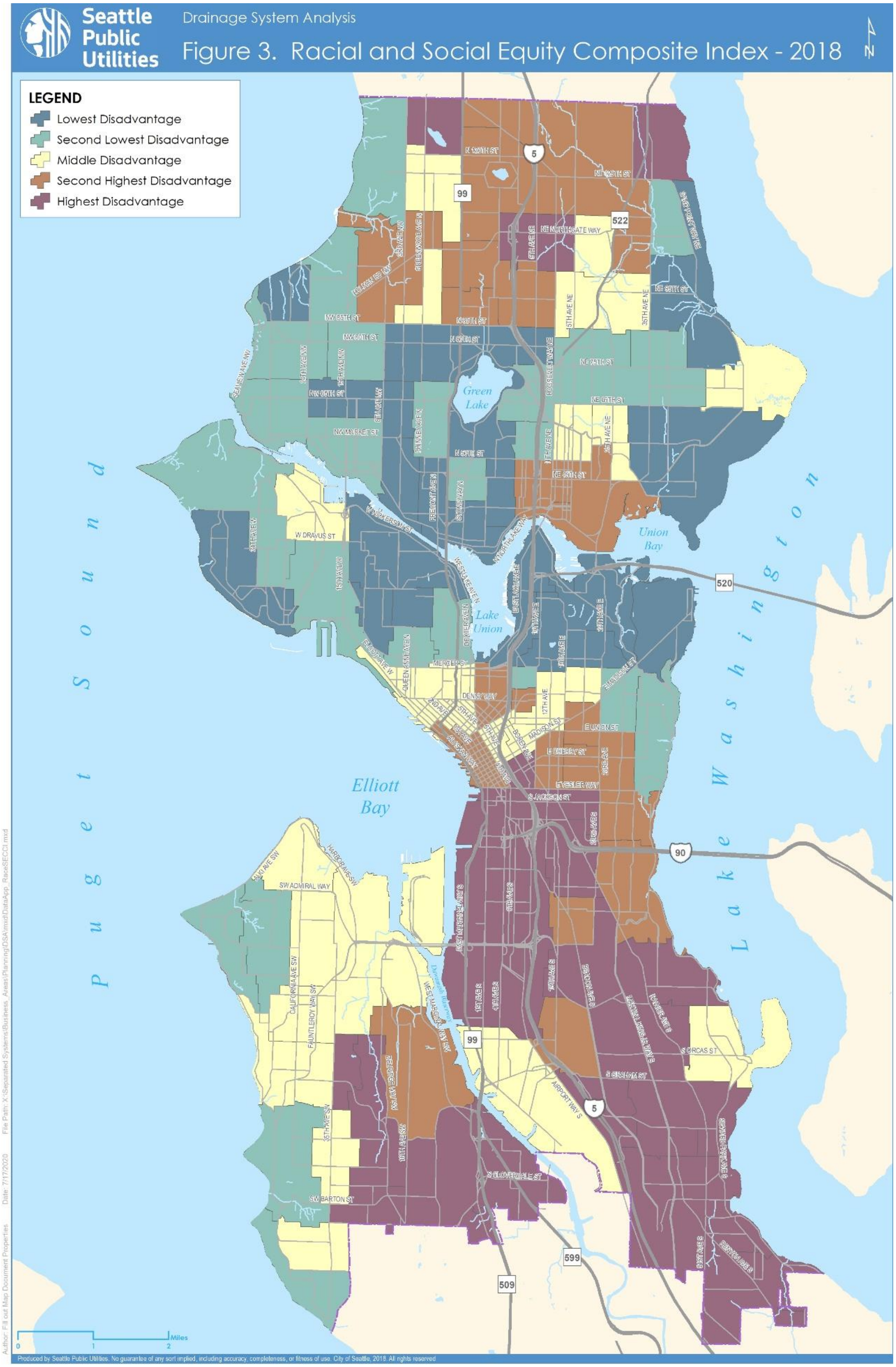
Figure 2. Critical Facilities
LEGEND
Emergency Services
High Population
Human Services
Medical
Protective
Support
Transportation
Vulnerable Population
Puget Sound
Elliott Bay
Green Lake
Lake Union
Union Bay
Lake Washington



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Drainage System Analysis
Figure 3. Racial and Social Equity Composite Index - 2018
LEGEND
Lowest Disadvantage
Second Lowest Disadvantage
Middle Disadvantage
Second Highest Disadvantage
Highest Disadvantage
Puget Sound
Elliott Bay
Lake Washington
Green Lake
Lake Union
Union Bay
Miles
0
1
2
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Drainage System Analysis
Figure 4. Snow and Ice Routes
LEGEND
Snow and ice route
Puget Sound
Elliott Bay
Lake Washington
Green Lake
Lake Union
Union Bay
Miles
0
1
2
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Table 2. Processed Data used in the Systems Analyses Projects

Name	Description	Storage Location(s)	File Name	Data Type	File Date	Analysis in Which the Data were Used				
						Wastewater system capacity risk areas	Drainage system capacity risk areas	Sea level rise risk map	Creek flooding risk map	Extreme storm event risk map
critical facilities	Point data of the following types of critical facilities: • emergency serviced • high population • human services • medical • protective • support • vulnerable populations The raw data were mapped by lat/long. Sites that mapped outside a parcel, were moved to the parcel based on the address and mapping review. The list was paired down to reflect facilities related to human health and safety for people at that location. See additional information below, after the tables. Exact duplicates were removed. List consists of 746 facilities on 612 unique parcels.	*DWW GIS Library on SharePoint* *Project files*	CriticalFac_rev.zip/.shp	point	12/21/18	✓				
critical facilities	King County parcel data developed from the critical facilities point data. Consists of parcels with at least one critical facility point within it.	*Project files*	CriticalFacility_parcels.shp	polygon	5/5/20		✓			
critical facilities	Raster data developed from critical facilities polygon data. A binary grid (4 foot by 4 foot) was developed by giving grid cells falling within the parcel polygons a value of 1 and all other cells were given a value of 0.	*Project files \rasterdata.gdb*	CritFacility	raster	7/17/20			✓	✓	✓
high use area	An area likely to have a large number of pedestrians traveling in or through it relative to other areas of the city. It consists of the following land uses and right-of-way (ROW) buffers: • Residential and Hub Urban Villages, including a 50-foot ROW buffer • Urban Center, including a 50-foot ROW buffer • Hospital campuses, including a 50-foot ROW buffer • Colleges and universities, including a 50-foot ROW buffer • Public and private schools, including a 50-foot ROW buffer • Link light rail stops, including a quarter mile ROW buffer • High frequency bus stops, including a 50-foot ROW buffer • Neighborhood greenways After each polygon data were buffered, they were merged into one data set.	*DWW GIS Library on SharePoint*	Pedestrian_Areas_for_Prioritization.mpk	polygon and polyline	1/7/19	✓ If at least 50% of a risk area included a high use area, the risk score was increased.				
high use area	Neighborhood greenways were buffered by the ½ of right-of-way width with the attribute "ROWWIDTH", equating to an area equal to the right-of-way width centered on the street polyline. The resulting polygon data were merged with the polygon data set of the other high use areas.	*Project files*	HighUseAreas.shp	polygon	7/15/20		✓			

Name	Description	Storage Location(s)	File Name	Data Type	File Date	Analysis in Which the Data were Used				
						Wastewater system capacity risk areas	Drainage system capacity risk areas	Sea level rise risk map	Creek flooding risk map	Extreme storm event risk map
high use area	Raster data developed from high use area polygon data. A binary grid (4 foot by 4 foot) was developed by giving grid cells falling within the high use area polygons a value of 1 and all other cells were given a value of 0.	*Project files \rasterdata.gdb*	HighUse	raster	7/17/20			✓	✓	✓
land area	Land within the city, and, except for Green Lake, no inland water bodies.	*DWW GIS Library (DSA) on SharePoint* *Project files*	CityofSeattle_DSA.zip/shp	polygon	3/25/20			✓	✓	✓
major transportation routes	From the streets data (Streets_DSA.shp), (1) Snow and ice routes were identified through a spatial join, and (2) interstates/freeways were identified based on attribute "OWNER" = "WSDOT". Identified features were merged into one dataset. Right-of-way widths (attribute "ROWWIDTH") of 60 feet were added to interstates/freeways. The polyline data were buffered by the ½ of right-of-way width equating to an area equal to the right-of-way width centered on the street polyline. A binary grid (4 foot by 4 foot) was developed by giving grid cells falling within the major transportation route polygons a value of 1 and all other cells were given a value of 0. (The dataset available has a grid cell value of 1.5 for major transportation routes.)	*Project files \rasterdata.gdb*	MajorTrans	raster	7/17/20			✓	✓	✓
Racial and Social Equity Composite Index	Polygon data were dissolved on the composite index. A binary grid (4 foot by 4 foot) was developed by giving grid cells falling within each disadvantage category the following value: • highest = 5 • second highest = 4 • middle = 3 • second lowest = 2 • lowest = 1	*Project files \rasterdata.gdb*	Equity	raster	7/17/20			✓	✓	✓
street type	Streets_DSA polyline data were buffered by the ½ of right-of-way width (attribute "ROWWIDTH") equating to an area equal to the right-of-way width centered on the street polyline. Snow and ice routes were identified through a spatial join. Major transportations are the routes with attribute "Type" = "SnowIceRoute". Non-arterial streets have the attribute "Type" = "Non-arterial".	*Project files*	StreetType_DSA.shp	polygon	5/5/20		✓			
streets	Street with right-of-way widths added to attribute "ROWWIDTH", where missing, when near a risk area. ROWWIDTHs added were based on aerial photo review.	*DWW GIS Library on SharePoint* *Project files*	Streets_DSA.zip/.shp	polyline	1/24/20		✓ (intermediate data set)			

DWW GIS Library on SharePoint = *https://seattlegov.sharepoint.com/sites/spu-D1/Planning/DWW%20GIS%20Library/Forms/AllItems.aspx*
DWW GIS Library (DSA) on SharePoint = *https://seattlegov.sharepoint.com/:f:/r/sites/spu-D1/Planning/DWW%20GIS%20Library/DSA/Data/SPU?csf=1&web=1&e=UBk4k2*
Project files = X:\Separated Systems\Business_Areas\Planning\DSA\data\Impacts

Table 3. Critical Facilities Included in Analyses

Category	Primary Use	Count
Emergency Services	Emergency Cache	4
Emergency Services	Fire - Support	1
Emergency Services	Government Function	2
Emergency Services	Medical	1
Emergency Services	Parking Garage	1
Emergency Services	Police Station	3
High Population	Conference Center	2
High Population	Landmark	1
High Population	Stadium	6
Human Services	Community Center	31
Human Services	Customer Service	4
Human Services	Family Center	7
Human Services	Food Bank	30
Human Services	Food Distribution Center	1
Human Services	Library	26
Human Services	Meal Program	17
Human Services	Non-Profit	10
Human Services	Shelter	22
Human Services	Support	4
Human Services	Teen Center	1
Medical	Blood Center	5
Medical	Dialysis Center	7
Medical	Hospital	12
Medical	Medical	1
Medical	Public Health	2
Medical	Urgent Care Clinic	17
Protective	Coast Guard Station	1
Protective	Fire - Support	1
Protective	Fire Headquarters	1
Protective	Fire Station	34
Protective	Joint: Fire Station / EOC	1
Protective	Joint: Fire Station / Senior Center	1
Protective	Joint: Police and Courts	1
Protective	Offices	1
Protective	Parking Garage	2
Protective	Police - Support	6
Protective	Police Harbor Patrol	2
Protective	Police Station	6

Category	Primary Use	Count
Support	Backup EOC	5
Transportation	Ferry Terminal	1
Vulnerable Population	Child Care Center	252
Vulnerable Population	Nursing Home	25
Vulnerable Population	School	90
Vulnerable Population	School - 6-12	2
Vulnerable Population	School - 6-8	10
Vulnerable Population	School - 9-12	13
Vulnerable Population	School - Gym	1
Vulnerable Population	School - K-5	59
Vulnerable Population	School - K-8	11
Vulnerable Population	School - Service School	2

Appendix D: Creek Flooding Risk Maps

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Seattle Public Utilities

Drainage System Analysis

Figure D-1. Risk Area for Fauntleroy Creek

Note: Urban watercourses may not align with risk areas in all locations. Urban watercourses do not always follow the lowest elevations reflected in the digital elevation model (DEM) used for inundation mapping. See Technical Memorandum for additional information.

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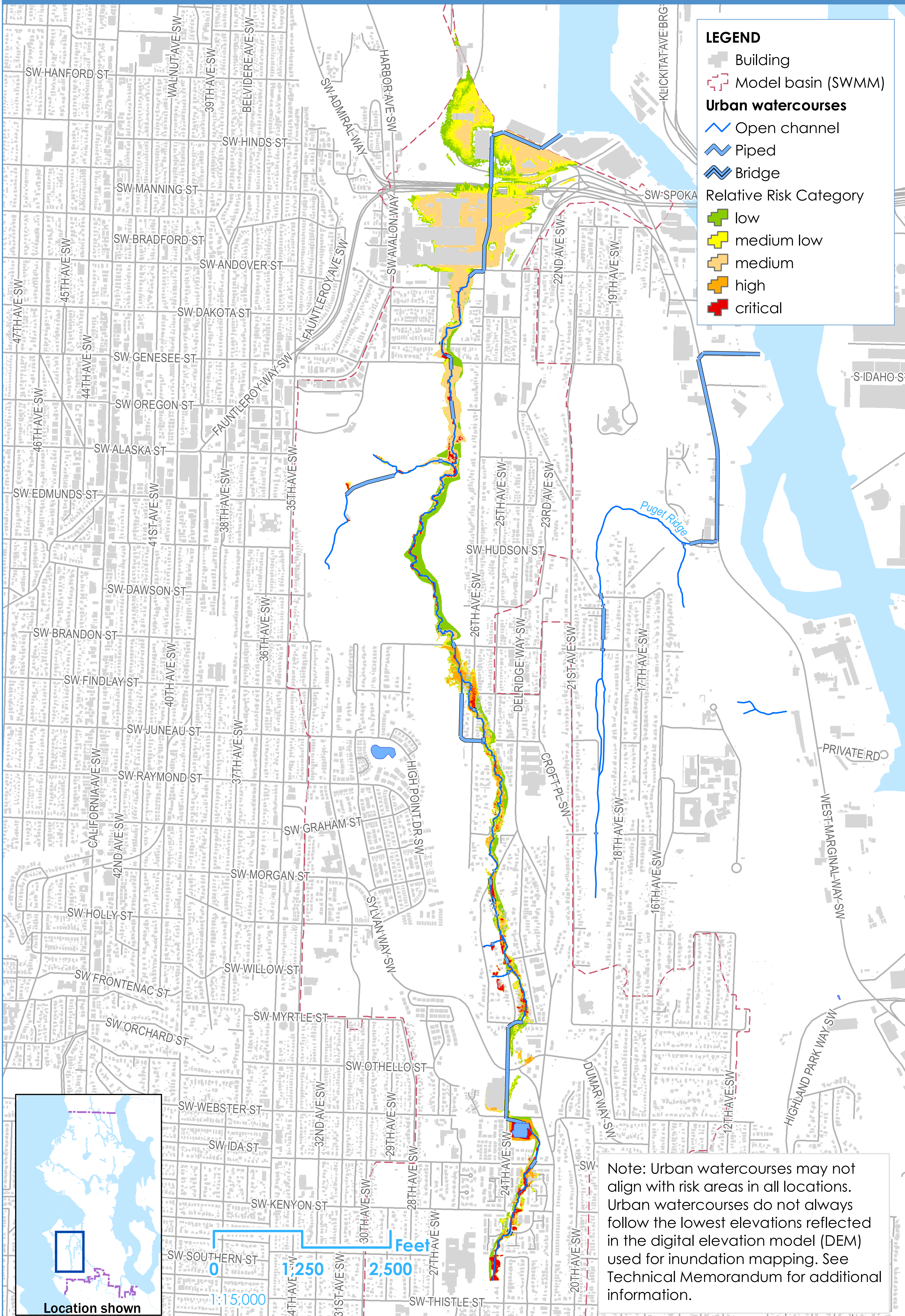
Seattle Public Utilities

Drainage System Analysis

Figure D-2. Risk Area for Longfellow Creek



Author: DSA Team   Date: 9/21/2020   File Path: X:\Separated Systems\Business_Areas\Planning\DSA\mxd\DSA_T2_Creeks_AppD_20200812_SPU.mxd

Seattle Public Utilities

Drainage System Analysis

Figure D-3. Risk Area for Taylor Creek

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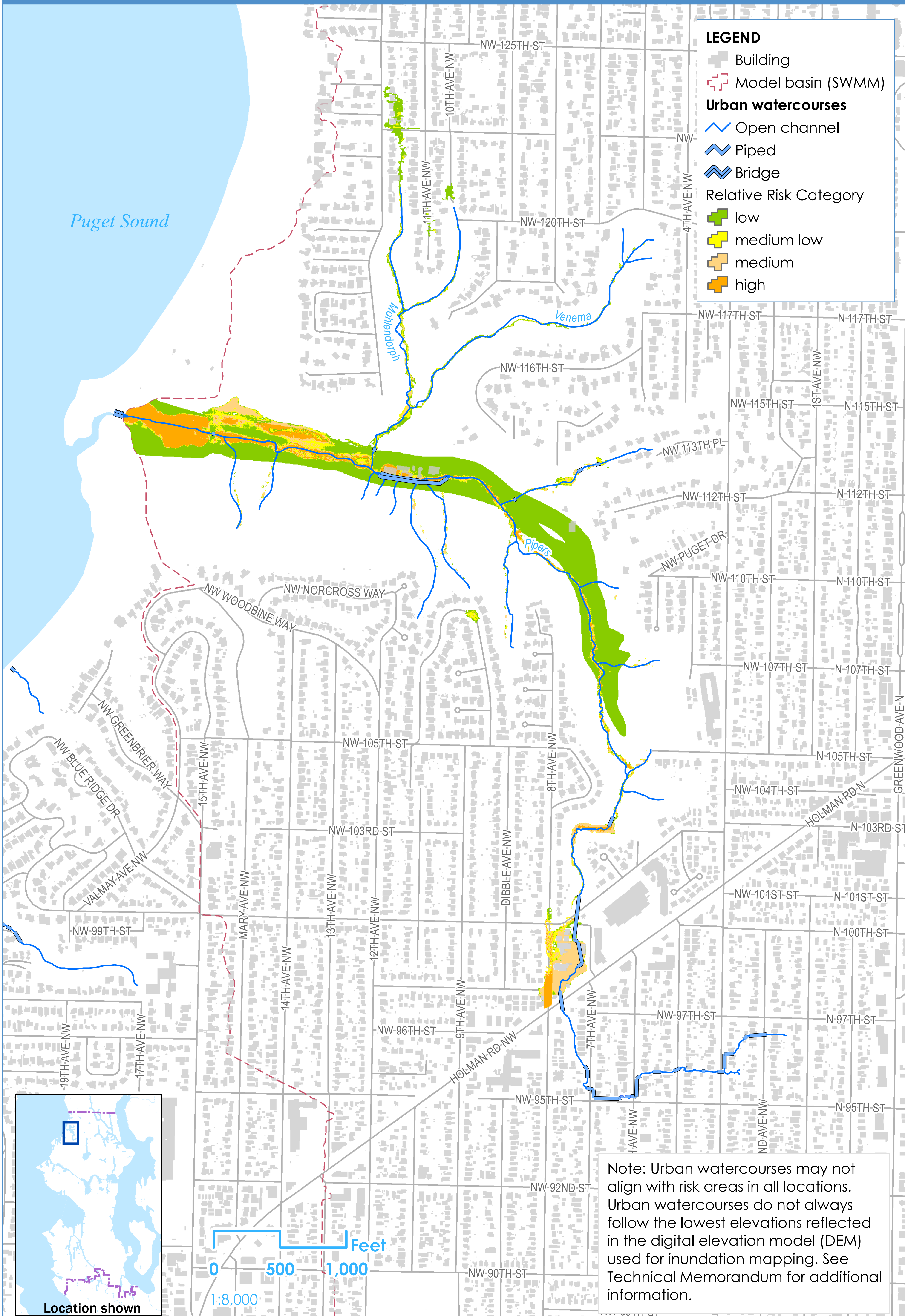
Seattle Public Utilities

Drainage System Analysis

Figure D-4. Risk Area for Piper's Creek

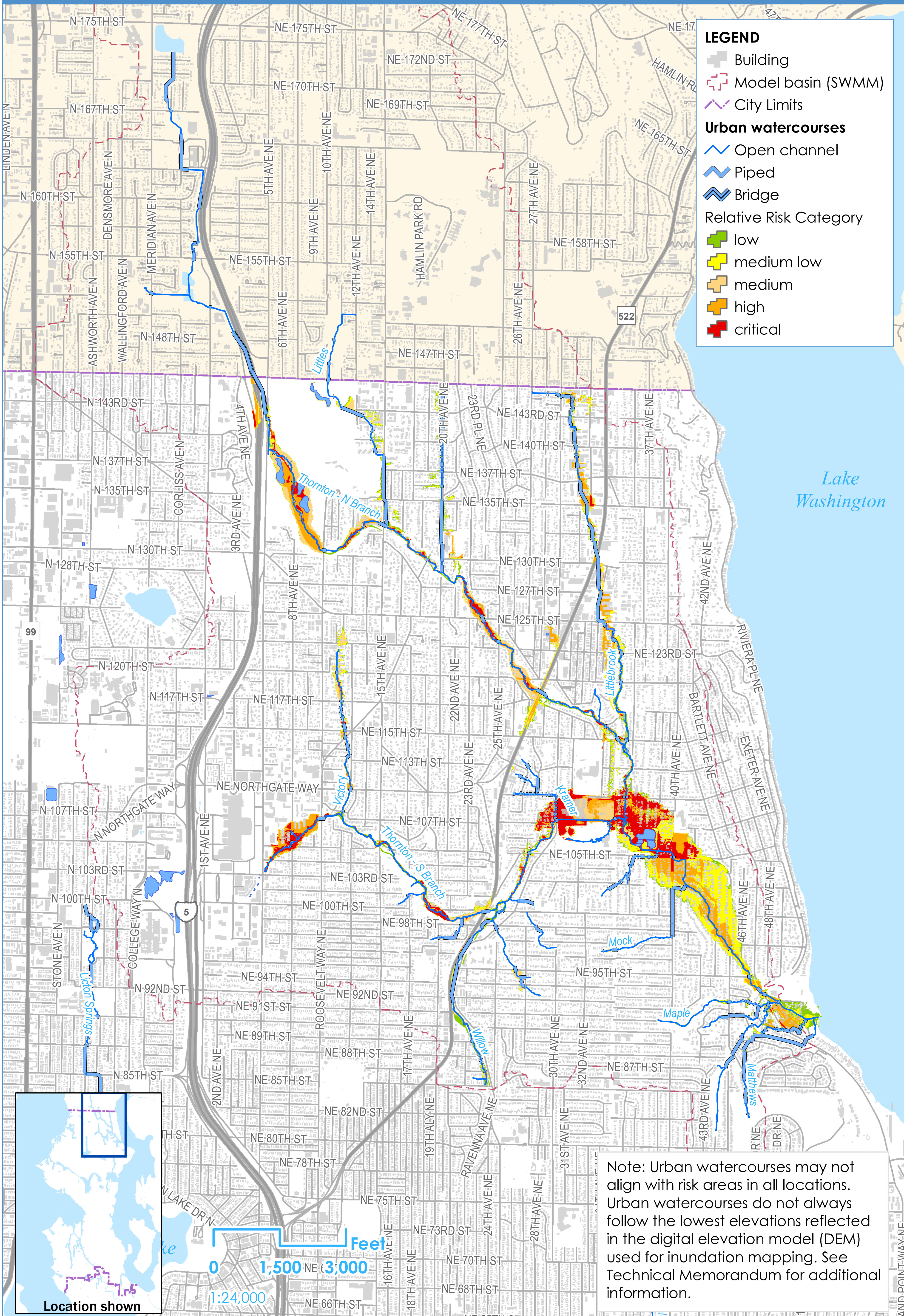


Author: DSA Team   Date: 9/21/2020   File Path: X:\Separated Systems\Business_Areas\Planning\DSA\mxd\DSA_T2_Creeks_AppD_20200812_SPU.mxd

Seattle Public Utilities

Drainage System Analysis

Figure D-5. Risk Area for Thornton Creek



Author: DSA Team Date: 9/21/2020 File Path: X:\Separated Systems\Business_Areas\Planning\DSA\mxd\DSA_T2_Creeks_AppD_20200812_SPU.mxd

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