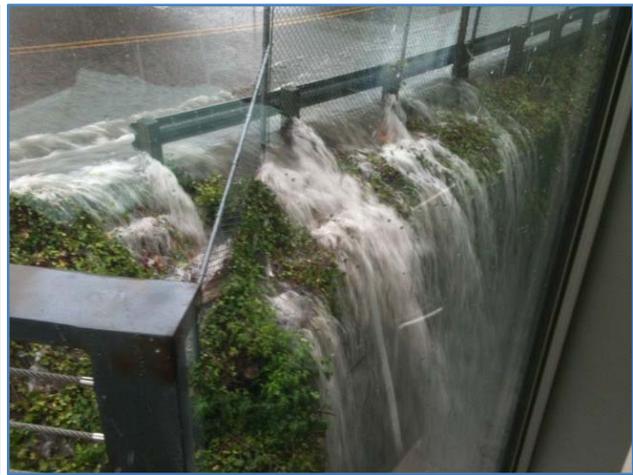


# Thea Foss Sub-Basins FS-05/FS-06 Stormwater Conveyance Plan

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Prepared by  
City of Tacoma Environmental Services



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## 1.0 CONVEYANCE PLAN GOALS

This Conveyance Plan (Plan) was developed to identify and improve existing storm sewer capacity issues and to plan for future development. This Plan is at a watershed scale and additional refinement in the model will be required as individual projects move forward.

This Plan covers storm sewer sub-basins FS-05 (Outfall 230) and FS-06 (Outfall 235). Stormwater conveyance planning for these two basins was done concurrently due to their relatively small size and opportunities to re-route flows between these basins.

## 2.0 EXISTING CONDITIONS

This section describes existing conditions in the FS-05 and FS-06 basins. In addition to a description of the land use and the capacity issues in these basins, a description of pipe condition is also provided since condition information may impact the conveyance alternatives (e.g., may be able to propose a new trunk line in an area where pipes are already in poor condition and need to be replaced).

Water quality data and water quality treatment devices in the basins are included in Appendix A. While this water quality information does not directly affect the capacity modeling, it is important information to consider when evaluating the basin relative to other areas within the City. The evaluation of capacity, condition, and water quality data in relation to other areas of the City is outside of the scope of this Plan and as such the condition and water quality information is meant only to provide the framework for future City-wide evaluations.

### 2.1 BASIN DESCRIPTION

The land use characteristics for each sub-basin are identified in Table 1 below. Combined, the FS-05 and FS-06 basins are currently 69% impervious. Additional details regarding the FS-05 and FS-06 basins are provided in the subsequent sections below.

**Table 1. Land Use Characteristics**

Basin Name	FS-05	FS-06
Area (Acres)	557	156
Open Space %	0	0
Residential %	26	3
Industrial %	0	0
Commercial %	74	97

#### 2.1.1 FS-05 (OF230) Drainage Basin

The FS-05 drainage basin is located on the mid-portion of the west side of the Thea Foss Waterway. The basin boundaries are shown on Figure 1. The area is approximately 557 acres and discharges to the waterway through a 60-inch outfall pipe located at South 15<sup>th</sup> Street and Dock Street in the right of way just south of Johnny's Seafood. The general basin boundaries are South 8<sup>th</sup> Street to the north, South 17<sup>th</sup> Street to the south, South Ainsworth Avenue to the west, and Dock Street to the east. Most of the storm drainage is channeled to South 15<sup>th</sup> Street

via a main trunk line along Market Street. Because of the steep downhill grade, overflow pipes exist in manholes along Market Street directing excess water to downstream trunk lines. Salt water enters the trunk lines along Dock Street during high tide events. Baseflow in FS-05 is continuous at approximately 0.12 cubic feet per second at the outfall.

The FS-05 drainage basin is heavily developed throughout with primarily commercial land use and some residential use on the west side of the basin (Table 1). The northern portion of the University of Washington–Tacoma discharges to FS-05. Also included in the basin are the Greater Tacoma Convention and Trade Center, downtown revitalization (condos and retail), Dock Street redevelopment, and the Foss Waterway Public Esplanade from South 17<sup>th</sup> Street to South 11<sup>th</sup> Street.

### **2.1.2 FS-06 (OF235) Drainage Basin**

The FS-06 drainage basin is heavily developed and covers an area of approximately 156 acres which drains through a 42-inch outfall pipe located on the west bank of the Thea Foss Waterway at South 21<sup>st</sup> and Dock Streets under the SR-509 bridge (Figure 1). The general basin boundaries are South 18<sup>th</sup> Street to the north, South 23<sup>rd</sup> Street to the south, South “L” Street to the west and Dock Street to the east. Baseflow in FS-06 is continuous at approximately 0.4 cubic feet per second.

Commercial land use accounts for the majority of the area in this basin (Table 1), with a small residential area on the western side. A small portion of freeway right-of-way is in the lower part of this basin including I-705 and the entire I-705 and SR-509 interchange. Most of the stormwater runoff from the freeways discharges to an infiltration pond and not to the City-owned storm drains.

The southern portion of the University of Washington–Tacoma and a portion of the St. Joseph Medical Complex discharges to FS-06. Also included in the basin is Tacoma Link Light rail, downtown revitalization, Dock Street redevelopment and the Foss Waterway Public Esplanade from South 21<sup>st</sup> Street to South 17<sup>th</sup> Street.

## **2.2 KNOWN CAPACITY ISSUES**

Known flooding issues and their believed impact in FS-05 and FS-06 are identified in Table 2 and on Figure 2. This list reflects information gathered from the source control database<sup>1</sup> and from personal communications with individuals in Science and Engineering and Transmission. Figure 2 also contains information gathered from the EOC database for both confirmed system capacity issues (i.e., notes in database indicate surcharged system) and potential system capacity issues<sup>2</sup>.

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<sup>1</sup> Due to the way that addresses are entered into the source control database (e.g., Ave vs. Avenue vs. Av.), it is difficult to plot the locations on a map. Therefore, the query of the source control database is likely incomplete and there may be additional flooding locations. This is discussed in more detail in Appendix D.

<sup>2</sup> These entries are entries in the EOC database that do not indicate why the road/street was flooded. These entries may indicate a capacity issue in the system, but they may also be due to a localized issue (e.g., leaves over a catch basin). Entries in the EOC database that were due to plugged catch basins (e.g., leaves, CB socks) are not shown on the map.

**Table 2. FS-05/FS-06 Known Flooding/Capacity Issues**

Basin	Location	Date	Issue (Believed Impact)	Data Source
FS-05	15 <sup>th</sup> & Pacific	Many, including 9/28/2013	Manholes at 15th and Pacific and downstream from Pacific surcharge during high intensity events. <i>(Annoyance to local businesses, but no reported property damage.)</i>	Source Control Database & Lorna Mauren
FS-05	17 <sup>th</sup> & Fawcett (6767098)	6/23/2013	Intersection flooded. <i>(Annoyance to local businesses, but no reported property damage.)</i>	Homeowner report to Kevin Brennan
FS-05	Tacoma Art Museum Parking (TAM) Lot (17 <sup>th</sup> & Pacific)	Many, including 6/23/13	Manholes on 17th surcharge; water flows across Pacific Ave. and into TAM parking lot. <i>(Potential to impact new TAM expansion. Affects access to/from TAM and the Courthouse. Cleanup required near loading dock at Courthouse.)</i>	TAM & AHBL
FS-05	9 <sup>th</sup> & Fawcett	Many, including 9/28/2013	Flooded intersection. <i>(Annoyance to local businesses, but no reported property damage.)</i>	Transmission (Madeline)
FS-05	9 <sup>th</sup> & Yakima	Many, including 9/28/2013	Flooded intersection. <i>(Annoyance to local businesses, but no reported property damage.)</i>	Transmission (Madeline)
FS-05	11 <sup>th</sup> & Broadway	Many, including 9/28/2013	Flooded intersection; out of CBs near TMB. <i>(Annoyance to local businesses, but no reported property damage.)</i>	Transmission (Madeline)
FS-05	16th & G St	Many, including 9/28/2013	CB surcharges. <i>(Annoyance to local businesses, but no reported property damage.)</i>	Transmission (Madeline)
FS-05	S. 15 <sup>th</sup> to 17 <sup>th</sup> on G St.	Many, including 9/28/2013	Flooded intersection. <i>(Annoyance to local businesses, but no reported property damage.)</i>	Transmission (Madeline)
FS-05	9 <sup>th</sup> & Pacific	Many, including 9/28/2013	Flooded intersection. <i>(Annoyance to local businesses, but no reported property damage.)</i>	Transmission (Madeline)
FS-06	Pacific between 21 <sup>st</sup> & 17 <sup>th</sup>	Many, including 9/28/2013	Flooding along Pacific Avenue. Up to doors at the Courthouse during some events in 2013. <i>(If water depth increases further, potential to cause damage in Courthouse.)</i>	Courthouse manager
FS-06	21 <sup>st</sup> & Pacific	Many	Surcharge at 21st and Pacific. <i>(Annoyance to local businesses, but no reported property damage.)</i>	Model/property owner

Information in the claims section of the source control database was reviewed to identify historic claims in the FS-05/FS-06 basins. Table 3 contains a list of historic claims<sup>3</sup> in the area.

**Table 3. Claims in FS-05/FS-06**

Address	Date	Complaint Notes
1142 Broadway	8/29/13	Taylor Baldunfs is the maintenance manager for the Broadway Plaza, 253-820-3904. The floor drain in the sprinkler / mechanical room on the second floor backed up. The piping in that room acted as a conduit to convey water to HVAC venting and into a first floor office building. Damage is limited to wet carpet and possible sheet rock damage. The flooding happened during a high intensity rainfall on 8/29/13, at approximately 5:00 PM. This is believed to be a stormwater backup.
1314 Market Street	8/29/13	Sandie Walker is the complex manager, 253-272-9475. The flooding occurred during an intense rainfall on 8/29/13, at around 5:00 PM. Six units and a pump room were affected. Each unit has a floor drain with a hot water heater plumbed to it. The drains receive overflow from the hot water heater. An approximately 6x6 area of each unit was affected. Each unit is 535 square feet or 22x24. On 9/4/13, City crews performed a dye test of a drain that flooded (unit 105). The connection of the drain is unconfirmed. Both sanitary and storm mains were monitored for dye confirmation for several hours. The drains may be connected to a French drain.
1314 Market Street	9/28/13	The Market Street Apartments backed up twice on 9/28/13. Once at noon and again at 5:00 PM. The fire department responded to the back up. Nine units and the site mechanical room were affected. The floor drains backed up and flooded the first floor. It is unknown how the floor drains are connected. This complex backed up on 8/29/13, from an apparent high intensity rain storm. A dye test on 9/4/13 was inconclusive. It is unknown how this business is connected to the municipal sewer. See claim # 13-CL-0063.

## 2.3 CONDITION INFORMATION

Pipe condition is assessed through video inspection of the pipes. This is done by either the Stormwater Rapid Assessment Program<sup>4</sup> (STRAP) or by traditional crawler cameras. The STRAP program is meant to provide a quick assessment of pipe condition, while the crawler cameras provide additional detailed information needed for capital improvement projects. The STRAP inspections and the crawler camera inspections are stored in separate databases.

When pipes are inspected by STRAP, the pipes are assessed as:

- Red – needs open cut repair/replacement,

<sup>3</sup> The claims review is incomplete due to the structure of the existing data. This is discussed in more detail in Appendix D. Only claims where no significant changes (e.g., new stormwater pipe in street) to the stormwater system have occurred since the claim occurred are listed in the Table 3.

<sup>4</sup> STRAP uses a hydraulically powered video camera to drive through the City's stormwater pipes. It is approximately five times faster than a traditional crawler cameras.

- Yellow – can be lined using CIPP, or
- Green – no action needed.

When inspected by crawler cameras, an engineer assessment is not necessarily performed and if an assessment is performed, it is not necessarily transferred into the STRAP rating system/database. For pipes that have been inspected via crawler cameras and are not included in the STRAP database, pipe condition is not quickly discernable<sup>5</sup> since each individual crawler camera video would need to be watched. Figure 3 shows the condition pipe assessments based on the current data in the STRAP database<sup>6</sup>.

In addition to the video inspection of the system, many of the pipes within these basins have been rehabilitated using Cured-In-Place Pipe (CIPP) construction technologies<sup>7</sup>. In 2010, 13,500 linear feet of storm sewer pipe in FS-05 were rehabilitated using CIPP. In 2013, an additional 13,807 linear feet in FS-05 and 5,479 linear feet in FS-06 were rehabilitated. These pipes are identified on Figure 4.

### 3.0 CAPACITY MODELING

#### 3.1 SIGNIFICANT MODEL CHANGES – BASE CONDITION

Below is a list of significant changes made to the Mike Urban model from the data that was originally exported out of GIS. Smaller modifications are not listed here, but can be determined by comparing the model components (e.g., nodes, links, outfalls) with the original shapefiles in the model folder.

- Added in new pipe infrastructure for South 17<sup>th</sup> Street from Court C to Commerce Street improvements using January 2014 plans. This will need to be updated as the project design is finalized.<sup>8</sup>
- Added in the pipe infrastructure for the A Street Storm Sewer Replacement Project (January 2014 – Bid set). Note: Upsized links 6291401 and 6291400 to 18” (instead of 15”) to eliminate flooding at the 100-year event in MH 6516486. This upsizing will be incorporated as a change order to the construction project.

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<sup>5</sup> See Appendix D for additional discussion on ways to improve this issue.

<sup>6</sup> The STRAP database has not been updated with the list of pipes that were CIPP lined in 2013 (see subsequent paragraph and Figure 4). Once the STRAP database is updated with this information, many more segments in the basin will be assessed as “green”.

<sup>7</sup> Resin impregnated liners are inserted into the main segments through existing manholes and the liner is then pressurized causing it to expand and form to the inside of the existing main segment. A source of heat is then applied which causes the resins to catalyze. The end result is a new pipe within the existing pipe that has similar strength and durability characteristics of PVC pipe.

<sup>8</sup> The model has since been updated to include the April 2014 plan set. The model will continue to be updated as additional revisions to the design are issued. Unless otherwise noted, this Plan includes the design based on the January 2014 plan set.

- Added Dummy MH A and B (and associated links) for SAP Line #6258807 (downstream from 15<sup>th</sup> and Pacific) based on video review. This video shows 52” pipe that enters a concrete box that is set at almost a right angle to the connecting pipes<sup>9</sup>. The box then connects into a 44” diameter reinforced concrete arch. This crawler camera video was reviewed since it is a key pipe to evaluate since it conveys the majority of the flows in FS-05.
- Rim of MH 6766944 was increased to elevation 38 ft based on field observations (similar in elevation to nearby manholes). Elevation in GovMe is likely based on original construction in the area and does not include fill above the original manhole.
- Replaced the ditch on South 21<sup>st</sup> between Yakima and South G Street with a pipe. This existing asphalt ditch is scheduled to be replaced with a pipe in an upcoming capital improvement project.
- Updated rims and inverts for manholes and pipes between Pacific and Court A on 15<sup>th</sup> Street based on actual survey (requested for this project). Submitted a request to have GovMe updated based on actual survey information. Note: A cross-connection was identified between MH 6766121 and MH 6767780. This cross-connection will be added to GovMe. This cross-connection is not included in the model, but an evaluation of the potential for stormwater to enter the sanitary system during peak events is described in Section 3.2.2.
- Updated inverts and pipe configuration near South 11<sup>th</sup> and Broadway based on a field investigation done as part of this modeling effort. Jeff Swinney will update GIS to reflect actual field conditions.

## 3.2 MODEL CALIBRATION

This section describes the process used to calibrate the Mike Urban model that was developed for FS-05 and FS-06.

### 3.2.1 Flow Meter Calibration

Several flow meters have been installed in the FS-05 and FS-06 basins. The locations and data quality for these meters are listed in Table 4 below.

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<sup>9</sup> The original plans (1936 plans, Work Order 1618) show a “removable cover”. It is not clear from the video inspection how this “removable cover” was addressed prior to placing additional fill material over the box. Video is available: <\\fsitst01\ESVideos\Video\REQ TVI - STORM 36 SEGMENTS VARIOUS LOCATIONS-6766953-6766944-109 S 15TH ST.mpg>

**Table 4. FS-05/FS-06 Meter Locations**

Basin	Meter Name	Location	Duration	Comments
FS-05	Storm 24	Downstream from 15 <sup>th</sup> & Pacific Line 6260436	10/8/07 to 9/27/11	Data is very questionable. Meter installed on a line that has a significant drop connection. Crews were not sure if they pushed the meter far enough up into the pipe.
FS-05	Storm 27	109 South 15 <sup>th</sup> St PVC Line 6258796	11/29/07 to unknown	All data unusable.
FS-05	Hood St	On Hood St, near 15 <sup>th</sup> Line 6258895	10/17/13 to current	Build up occurs on the sensor during low flows. Data ok for larger events.
FS-06	Storm 23a	21 <sup>st</sup> & Pacific Line 6261338	9/25/07 to 2/26/09	Installed on very steep slope. Tried to calibrate the data, but it didn't match model predictions. Per Steve Shortencarrier, level data is very questionable.
FS-06	21 <sup>st</sup> & Pacific	21 <sup>st</sup> & Pacific Line 6288140	10/30/13 to current	Velocity is very flashy. Low flows likely are not reliable.

Based on the Mike Urban modeling guidance, the initial model runs were run with a 75% reduction factor on the impervious layers. This reduces the percent impervious of each catchment to 75% of the actual impervious percentage (i.e., a basin that is 100% impervious is modeled as a basin that is 75% impervious). This reduction factor can be modified during model calibration to get good agreement between the model and the meters/observed conditions.

Model calibration was checked against the following storms events<sup>10</sup>:

- 11/06/08 (2.7 inches in 32 hours, peak of 0.09 in/15 min) – Compared to Storm 24 meter (see Figure 5 attached). The blue line represents the meter information and the black line represents the model prediction.
- 1/11/14 (1.01 inches in 14.25 hours, peak of 0.08 in/15 min) – Compared to 21<sup>st</sup> and Pacific meter (see Figure 6 attached). The blue line represents the meter information and the black line represents the model prediction. *(Note: This calibration run appears to show the model slightly under predicting actual flows. Since this rain event was fairly small, more significant events should be modeled prior to modifying the calibration.)*
- 2/16/14 (2.25 inches in 10.5 hours, peak of 0.08 in/15 min) – Compared to Hood Street meter (see Figure 7 attached). The blue line represents the meter information and the black line represents the model prediction. *(Note: Flow data for the 21<sup>st</sup> and Pacific meter for this same event is poor quality. Request sent to crews to perform a site*

<sup>10</sup> Calibration events are very sensitive to the rainfall inputs. For the FS-05 and FS-06 subbasin modeling, rain data collected at the Central Treatment Plant (2201 Portland Ave) was used to estimate the actual rainfall that landed on the basins.

*investigation and make fixes, as needed. The sensor likely needs to be swept or needs to be replaced.)*

As additional data becomes available from the Hood Street and the 21<sup>st</sup> and Pacific meters, model calibration should be reviewed again. The current calibration events are fairly small and larger events recorded from these meters should be used as it becomes available.

### **3.2.2 Calibration Compared to Known Capacity Issues**

Figures 8 and 9 show the model results for a 100-year event (Type 1A, 24-hour<sup>11</sup>) and the recent September 28, 2013 event when several flooding observations (Table 2) were observed. The figures show the maximum node flood<sup>12</sup> and the maximum percent full of the pipe<sup>13</sup> during these events.

The flooding issues identified in Table 2 are generally evident in the modeling results for the September 28, 2013 event (Figure 9) with the exception of 17<sup>th</sup> and Fawcett. Due to this discrepancy, the main at 17<sup>th</sup> and Fawcett was inspected by the I&I crew. During this investigation, they noted that this manhole had pulsating flows during a rain event<sup>14</sup>. This suggests there is a hydraulic issue upstream of this location. Additional investigation upstream would be needed to identify the cause.

Initial modeling efforts did not identify a significant issue near 15<sup>th</sup> and Pacific (included in Table 2). Once the video for SAP Line #6258807 was reviewed (see Section 3.1), however, and the model updated to incorporate the significant bend in the pipe and pipe diameter reduction (52" to 44"), manhole surcharging similar to the observed conditions near 15<sup>th</sup> and Pacific became evident. Additional information is needed to better determine the actual size of the concrete box (e.g., height and width), the actual diameter of the 44" reinforced arch pipe, and the location of the start and end of the box relative to the pipes (e.g., what are the actual angles) in order to better model this system. Minor changes in these assumptions can have a significant impact on the predicted flooding at 15<sup>th</sup> and Pacific.

As noted in Section 3.1, there is a sanitary to stormwater cross-connection between MH 6766121 (sanitary) and MH 6767780 (storm) just downstream from 15<sup>th</sup> and Pacific. Based on survey of the cross-connection, the invert in the sanitary manhole for this cross-connection is 36.99 ft. Based on the predicted water levels in MH 6767780 during the September 28, 2013 event (Figure 10), stormwater may have been flowing into the sanitary system between 4:55 PM

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<sup>11</sup> The Type IA distribution file used in all Mike Urban modeling to date does not match the distribution currently available from the Soil Conservation Service (SCS). The peak intensity for a 100-yr, Type 1A, 24-hour event based on the SCS distribution is 0.16 in/10 minutes. The peak intensity for a 100-yr, Type 1A, 24-hour event based on the file that has been used for all historic (including this model) Mike Urban modeling is 0.22 in/10 minutes. Whenever this Plan refers to the 100-year event, it is based on a model run with a 0.22 in/10 minute peak intensity.

<sup>12</sup> Water elevation relative to rim elevation. Positive numbers indicate water surcharging manhole.

<sup>13</sup> Pipes that are greater than 100% full are running as pressure pipe during a portion of the event. The difference between yellow and red is an indication of how much pressure the pipe is under.

<sup>14</sup> Video available for review here: <G:\Collection System Support\I&I\storm manhole surging>

and 5:05 PM<sup>15</sup>. A meter has been installed in this cross-connection pipe and this information will be used to further calibrate this system.

### 3.3 STORM TRUNK MAIN OPTIONS

This section explores options to reduce the amount of flooding in FS-05 and FS-06 (especially at 17<sup>th</sup> and Pacific which has the possibility of impacts to TAM operations).

#### 3.3.1 Existing Conditions with Development

The entire basin is roughly 69% impervious currently (Figure 11). If additional development occurs on all the vacant properties and the currently underutilized properties<sup>16</sup> (Figure 11), the percent impervious of the basin would increase to approximately 74%. For the purposes of identifying potential alternatives, this development scenario (identified as Dev A in the Mike Urban model runs) was modeled. Other development scenarios are explored (see Section 4.4) once the preferred alternative is identified.

With the additional development in scenario Dev A, existing flooding will increase and new flooding issues will be created. Model predictions for current conditions compared to scenario Dev A for some of the key areas are listed in Table 5.

**Table 5. Predicted Flooding at Key Locations**

Location	SAP#	Max Node Flood <sup>a</sup>	
		Existing Development (100-yr, Type 1A, 24-hour event)	Development Scenario (Dev A) (100-yr, Type 1A, 24-hour event)
15 <sup>th</sup> & Pacific	MH6766908	+2.1 ft	+2.1 ft
17 <sup>th</sup> & Pacific	MH6767834	+2.9 ft	+3.2 ft
21 <sup>st</sup> & Pacific	MH6767411	+1.7 ft	+2.5 ft

a - Maximum elevation of water during the event relative to the rim elevation

To fix the surcharging at these three locations, pipes downstream from these locations would need to be upsized. Directional drilling would likely be required at all three locations:

- 21<sup>st</sup> and Pacific to get under the Link light rail tracks.
- 17<sup>th</sup> and Pacific to get under the Link light rail tracks.

<sup>15</sup> Until modifications are made to the storm system to eliminate this discharge (by re-routing flows, upsizing pipes, etc.), it is recommended to keep this cross-connection active to provide relief for the storm sewer system during peak events. This line needs to be metered to determine if the magnitude, direction (stormwater to wastewater or vice versa), and frequency of the discharges. There is the potential for wastewater to enter the stormwater system if the wastewater system has a blockage downstream.

<sup>16</sup> Properties that are currently zoned for a higher use (e.g., zoned commercial, but are currently being used as residential).

- 15<sup>th</sup> and Pacific to fix the concrete box/pipe constriction at Line #6258807 (see Section 3.1 for additional information) and get under the BNSF tracks.

In order to keep costs down and reduce the impacts of construction on downtown businesses and residents, scenarios were modeled to determine if flows could be rerouted so that one or two corridors rather than all three need to be upsized.

### 3.3.2 Divert Flows North (Pink Routes)

Diverting flows north in FS-05 and FS-06 is challenging since the ground generally slopes north to south. The best alternatives to direct flows north are either the Jefferson Street corridor or the Hood Street corridor since these corridors are in the northeast (rather than north-south) direction. Due to upcoming construction in Hood Street during summer 2014, this alternative was not viable due to the impact the new trunk line would have on the project's construction schedule.

Therefore, the Jefferson Street corridor was selected as the preferred corridor to direct flows north from 21<sup>st</sup> Street<sup>17</sup> to 17<sup>th</sup> and Pacific. In order to resolve the issues at 15<sup>th</sup> and Pacific (Table 2), a new trunk line was installed in Fawcett<sup>18</sup> to connect 15<sup>th</sup> to 19<sup>th</sup> Street<sup>19</sup>. This new trunk line, which takes all flows upstream from 15<sup>th</sup> and Fawcett, successfully eliminates the flooding issues at 15<sup>th</sup> and Pacific under scenario Dev A.

Once the connection across 17<sup>th</sup> and Pacific is made under the Link light rail, the new trunk main can connect back into the existing OF230 trunk main (this would require upsizing all pipes downstream of the connection point to the outfall) or could discharge into a new outfall. There is an existing unutilized utility corridor south of the Esplanade condos on Dock Street that could be used for the new outfall.

Both of these alternatives are shown as the pink lines (solid and dashed) on Figure 12. As identified on the figure, options to extend the new trunk line north to 9<sup>th</sup> Street could also be explored as ways to reduce flooding in the north end of the FS-05 basin. Since this alternative is identical in both the pink (divert flows north) and blue (divert flows south) scenarios, this is not discussed in more detail here. This extension is discussed in more detail in Section 4.1.

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<sup>17</sup> A model scenario was run to see if only taking flows from 19<sup>th</sup> St & Jefferson north to 17<sup>th</sup> would remove enough flow from the 21<sup>st</sup> street line to prevent flooding at 21<sup>st</sup> & Pacific. Under development scenario Dev A, however, the model still predicted flooding at 21<sup>st</sup> & Pacific. Since the area near 19<sup>th</sup> and 21<sup>st</sup> Streets between Pacific and Tacoma Avenue has a very high likelihood for redevelopment (due to UWT expansion), it is recommended to extend the trunk main to 21<sup>st</sup> Street to prevent future issues at 21<sup>st</sup> & Pacific. This connection between 19<sup>th</sup> and 21<sup>st</sup> does not need to happen immediately, but the trunk main in Jefferson is sized to handle the additional flows that are expected when the connection is made.

<sup>18</sup> Other streets could be used to make this north-south connection. Fawcett was selected in this alternatives analysis since the street is generally in poor condition and provides an opportunity to divert a significant amount of flow into the new trunk main. During the design process for the new trunk line, other streets should be explored for the connection between 19<sup>th</sup> Street and 15<sup>th</sup> Street.

<sup>19</sup> Alternatively, the project could connect 15<sup>th</sup> Street to 17<sup>th</sup> Street on Fawcett and then connect 17<sup>th</sup> & Fawcett to 17<sup>th</sup> & Jefferson (see alternative on Figure 12). Total linear footage of new pipe would be roughly the same. This alternative should be explored during the design phase.

### 3.3.3 Divert Flows South (Blue Routes)

Under this scenario, new pipes were installed to connect 15<sup>th</sup> Street to 21<sup>st</sup> Street (flow direction from 15<sup>th</sup> to 21<sup>st</sup> on Fawcett<sup>20</sup>). This scenario takes all flows upstream from the connection points (e.g., west of Fawcett Street) and diverts them to 21<sup>st</sup> Street. This new trunk main was able to successfully divert enough flows from the 15<sup>th</sup> Street and 17<sup>th</sup> Street lines to eliminate flooding under future development scenario Dev A at 15<sup>th</sup> and Pacific and 17<sup>th</sup> and Pacific.

In order to eliminate the flooding at 21<sup>st</sup> and Pacific with the additional flows from the new trunk main, it was determined that all three immediate downstream segments (link 6288140, link 6261338, and link 6261350) would need to be upsized. This would necessitate directional drilling (due to I-705 and the BNSF tracks) from the outfall across Pacific. This drill would be in close proximity to the I-705/SR-509 interchange and would be very challenging to accomplish. In addition, there would be significant traffic impacts since two drilling pits (one at outfall, one in middle of I-705/21<sup>st</sup> St interchange) would be required due to the length of the drill.

Another potential alternative that diverts flows to the south consists of taking flows past 21<sup>st</sup> Street south to 23<sup>rd</sup> Street. The new trunk line could then head east on South 23<sup>rd</sup> and cross under I-705. A new outfall would be installed in the park at 21<sup>st</sup> and Dock Street. This alternative would install a new outfall in the south end of the Thea Foss Waterway, which may be challenging due to the Superfund permit requirements.

Both of these alternatives are shown as blue lines (solid and dashed) on Figure 12. As discussed in Section 3.3.2 above, options to extend the new trunk line north to 9<sup>th</sup> Street could also be explored as ways to reduce flooding in the north end of the FS-05 basin. This extension is discussed in more detail in Section 4.1.

### 3.3.4 Recommended Alternative

The south diversion has significant challenges with drilling near the 21<sup>st</sup> and I-705/SR-509 interchange and with installing a new outfall in the Utilities work area of the Thea Foss Waterway Superfund site. Due to these significant issues, the north diversion (pink route) is the preferred alternative.

The remainder of this Plan discusses the various scenarios (rain, development) for the north diversion option in order to determine preliminary pipe sizing. Actual sizing will be updated as the design for the new trunk main progresses.

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<sup>20</sup> A scenario was also run to connect 15<sup>th</sup> Street to 21<sup>st</sup> Street on G Street. Since the model results are similar, they are not discussed in detail here. Other streets could be used to make this north-south connection. During the design process for the new trunk line, other streets should be explored to see if they would be a better option.

## 4.0 TRUNK MAIN SIZING

Trunk main sizing is an iterative exercise as each alternative requires that upstream pipes are upsized so that flows remain in the pipe and travel downstream. Mike Urban does have the capability of adding surface flow to divert flows that surcharge from manhole to downstream structures. This process, however, is time consuming to model and there is the potential for damage to property due to this surface flow. Therefore, the goal for all scenarios was to keep the water inside the pipe during the various scenarios.

### 4.1 CONNECTION FROM 15<sup>TH</sup> TO 9<sup>TH</sup> STREET

The model (model run: DevA\_JeffSt\_Full\_All\_100yr) indicates that the flooding at 9<sup>th</sup> and Fawcett, 9<sup>th</sup> and Yakima, and 11<sup>th</sup> and Broadway (Table 2) cannot be eliminated without either:

- Fixing the concrete box/pipe constriction at 15<sup>th</sup> and Pacific (see Section 3.1), or
- Making a connection between 15<sup>th</sup> Street and 9<sup>th</sup> Street on Fawcett.

Determining which of these options to move forward with is dependent on the decision on whether or not to replace the existing OF230 or install a new outfall. If the existing OF230 is going to be upsized (i.e., the concrete box/pipe constriction will be replaced to accommodate the additional flows), the connection between 15<sup>th</sup> and 9<sup>th</sup> Street on Fawcett may not be needed. If, however, a new outfall south of the Esplanade condos is the preferred corridor, making the connection between 15<sup>th</sup> Street and 9<sup>th</sup> Street may be the best option.

### 4.2 UPSTREAM UPSIZING

Pipes in the basin were upsized (model run: DevA\_JeffSt\_to9th\_100yr<sup>21</sup>) in order to keep water levels below manhole rims during a 100-year, Type 1A, 24-hour event under the development conditions (Dev A) identified in Section 3.3.1. A map showing all the pipes that would need to be upsized is shown in Figure 13.

Please note that there are often multiple alternatives to upsizing specific pipes (e.g., can change pipe slope, can change pipe depth, can upsize downstream pipes to reduce backwater conditions) and each of these options would need to be investigated in more detail during the design phase of a capital project. Figure 13 should be used as a general guide to identify pipes that may need to be upsized in the basins<sup>22</sup>.

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<sup>21</sup> Note: This assumes that a connection will be made from 15<sup>th</sup> St to 9<sup>th</sup> St. If this connection is not made, some additional changes made be needed downstream.

<sup>22</sup> This list does not prioritize which pipes are most critical to being upsized within these basins or within the entire storm system. This information needs to be combined with condition information and the consequence of failure/flooding information to make those determinations. This is outside of the scope of this Plan. Many of the pipes identified on Figure 13 meet capacity requirements under current development conditions and may only need to be upsized as future development occurs.

### 4.3 RAIN EVENT FOR SIZING

To test the impact of higher intensities (model run: DevA\_JeffSt\_to9th\_062313), the model was run using the rainfall data from the June 23, 2013 event recorded at the Northeast Tacoma rain gauge. This event had a maximum intensity of 0.35 in/10 minutes (100-year event has maximum of 0.22 in/10 minutes). The initial model run identified issues in the trunk main on Fawcett between 15<sup>th</sup> and 11<sup>th</sup>; this pipe was upsized by one foot to accommodate the additional flow.

The remainder of the system was not modified due to this extreme peak intensity event. Figure 14 shows the predicted flooding locations in the system. Additional research into these locations would be needed to determine if any upsizing is warranted (e.g., would flooding have a high potential for significant impacts to human health or property.) Options to install overflow pipes into other areas of the system (e.g., into the 17<sup>th</sup> or 21<sup>st</sup> Street lines which are oversized once the new trunk line is installed) should also be explored.

### 4.4 DEVELOPMENT CONDITIONS

The entire basin is currently approximately 69% impervious. Since a 75% factor (see Section 3.2.1) was applied to the actual impervious, the model under current development conditions had an average percent impervious of 51.9% ( $69\% * 0.75$ ).

Under development scenario Dev A, all the vacant properties and the currently underutilized properties (see Figure 11), are assumed to be fully impervious. This increases the percent impervious of the basin to approximately 74%. Since a 75% factor was applied to the actual impervious, the model under Dev A had an average percent impervious of 55.4% ( $74\% * 0.75$ ).

In order to assess the impact of additional future development, the 75% factor used in Dev A was changed to 85% for development scenario Dev B (model run: DevB\_JeffSt\_to9th\_100yr). This increases the model percent impervious to 65.4% from 55.4%. The results of this modeling are shown in Figure 15. Please note that areas of downtown that are already essentially fully developed are not likely to actually increase in their imperviousness so the model likely over predicts the impacts that will occur in the areas that are already fully developed.

### 4.5 DEVELOPMENT AND RAIN EVENT COMBINED

The system was modeled (DevB\_JeffSt\_to9th\_062313) assuming the June 23, 2013 event (see Section 4.3) and development scenario Dev B<sup>23</sup> (Figure 16).

Everything that flowed to the new outfall was upsized to prevent surcharging of any of the manholes in order to test the sizing of the new trunk main. The model (DevB\_JeffSt\_to9th\_062313\_FIXED) suggested the portions of the trunk main needed to be upsized in several locations in order to keep water inside the manholes. Pipe sizing to account for this additional flow is shown in Figure 17. This will need to be updated as the design progresses based on updates to the model calibration, actual inverts, the rain events actually used for sizing, and the development scenarios.

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<sup>23</sup> This set of models were run with the April 2014 plan set for the new pipes in 17<sup>th</sup> and Jefferson.

## 5.0 TRUCK MAIN MODELING – NEXT STEPS

As described in Section 4, there are multiple scenario runs which all have different impacts on the system<sup>24</sup>. In order to select the most appropriate scenario, the following items are needed:

- Update/verify model calibration after large storm events are captured by the Hood Street and the 21<sup>st</sup> and Pacific meters.
- Investigate the concrete box and 44” arch pipe downstream of 15<sup>th</sup> and Pacific to determine the current condition. If this pipe is not in good condition and cannot be rehabilitated, this may affect the alignment of the truck main (i.e., upsize existing OF230 alignment or new outfall). Steve Hoffman will hire a consultant to evaluate the current condition and to propose rehabilitation options.
- Video inspect key trunk lines that have not currently been assessed. The highest priority inspections are Line #6259959 (segment in FS-05 that goes under BNSF tracks on Dock Street<sup>25</sup>) and Line #6261350 (segment in FS-06 that goes from Pugnetti Park to Dock Street under BNSF tracks). Request was placed with Mike Rose to get these inspections done.
- Determine the viability of directional drilling for both of the north route options (e.g., new outfall or upsize existing OF230). In order to continue modeling these options, more information is needed about where the directional drilling access points would be and what the inverts would be for these new directionally drilled pipes.
- Investigate existing utilities along the trunk main proposed route to determine potential conflicts. Adjust model inverts and pipe sizes accordingly.
- Continue to investigate the impact various development options and rain events have on the system once the alignment options are settled. Since the new trunk main takes all flows from the upstream areas, the existing downstream systems (e.g., pipes in 21<sup>st</sup> and Pacific, pipes in 17<sup>th</sup> and Pacific, and pipes in 15<sup>th</sup> and Pacific) will have excess capacity. Installing overflow pipes into these existing systems would be one way to balance future flows in the system. The need for and the inverts of these overflow pipes should be explored as modeling progresses.

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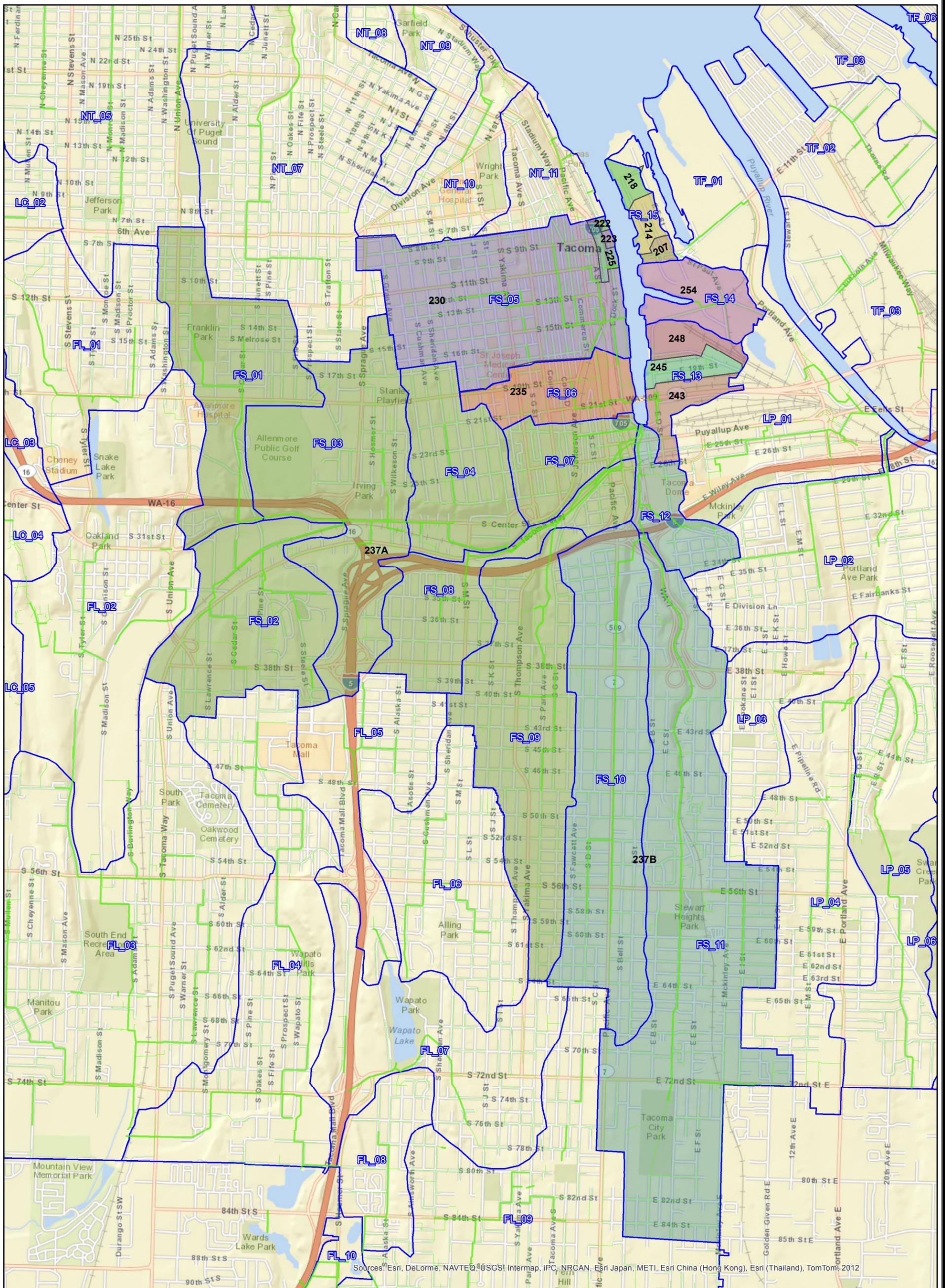
<sup>24</sup> Many of the various scenarios were explored prior to having all the required information so that the new trunk line in Jefferson Street between 17<sup>th</sup> and 19<sup>th</sup> could be installed in summer 2014. This trunk line in Jefferson needs to be designed to be flexible enough to handle various future scenarios.

<sup>25</sup> Line was video inspected previously, but the inspection was done under high tide conditions so no condition information could be determined from the video.

# FIGURES

# Figure 1

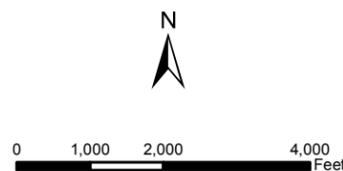
## Stormwater Sub-Basins In the Thea Foss Basin (2013)



Sources: Esri, DeLorme, NAVTEQ, USGS, Intermap, iPC, NRCAN, Esri Japan, METI, Esri China (Hong Kong), Esri (Thailand), TomTom, 2012

**Legend**  
 STORM LINES  
 TRUNKLINES 24" AND LARGER

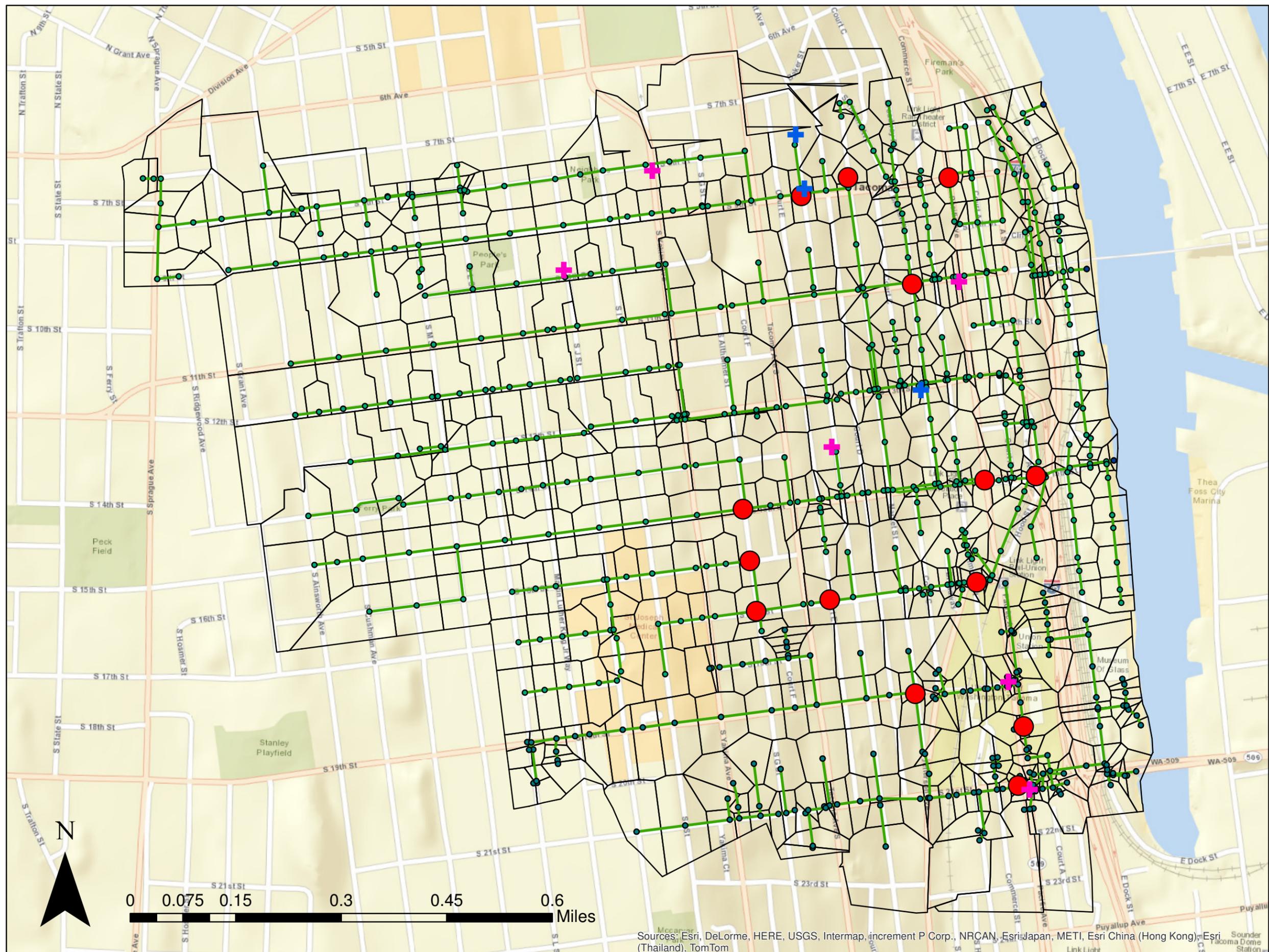
Map Date: February 22, 2013  
 Source: Environmental Services Division,  
 Public Works Department City of Tacoma  
  
 Center for Urban Waters  
 326 East D Street, Tacoma WA 98421  
 (253) 591-5588



STORM SUB-BASINS



**Figure 2.**  
**FS-05 and FS-06 Known**  
**Flooding Locations**



- Confirmed Flooding Areas
- ⊕ EOC Entry - Confirmed System Surcharge
- ⊕ EOC Entry - Potential System Surcharge

Sources: Esri, DeLorme, HERE, USGS, Intermap, increment P Corp., NRCAN, Esri Japan, METI, Esri China (Hong Kong), Esri (Thailand), TomTom

**Figure 3.**  
**FS-05 and FS-06 STRAP**  
**Assessments**

- Red
- Yellow
- Green
- Not Assessed

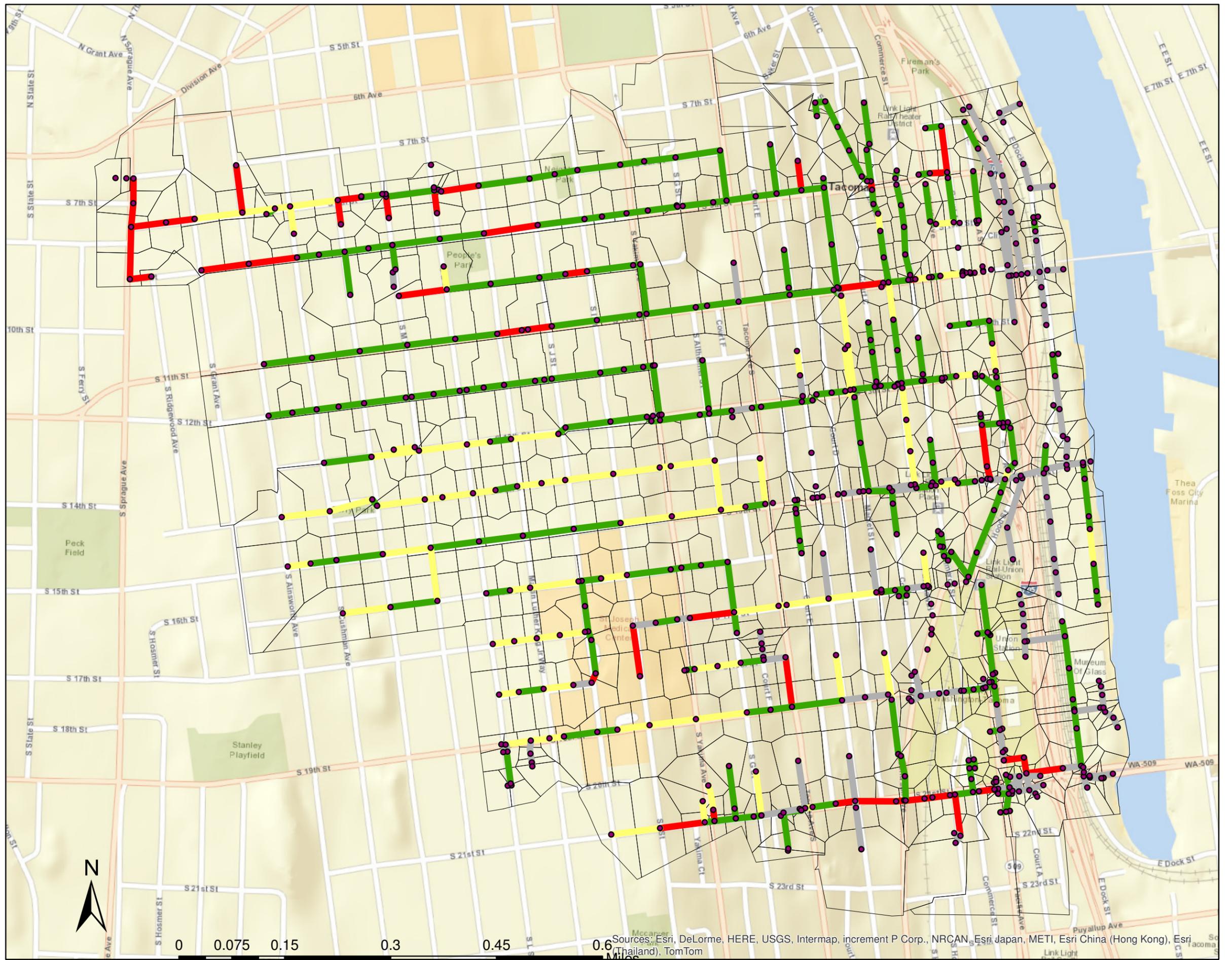
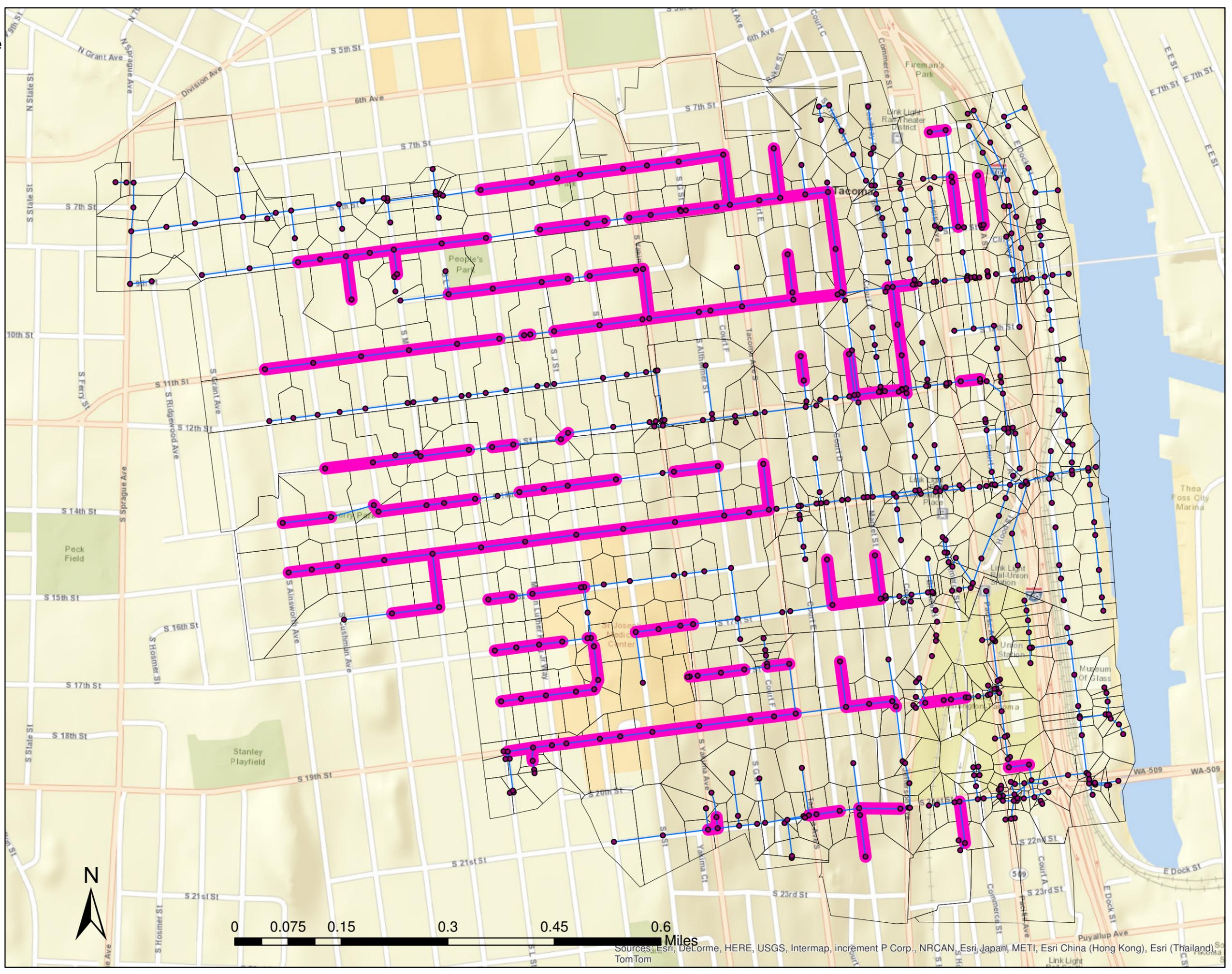


Figure 4.  
FS-05 and FS-06 CIPP Lined Pipe

 CIPP Lined Pipe

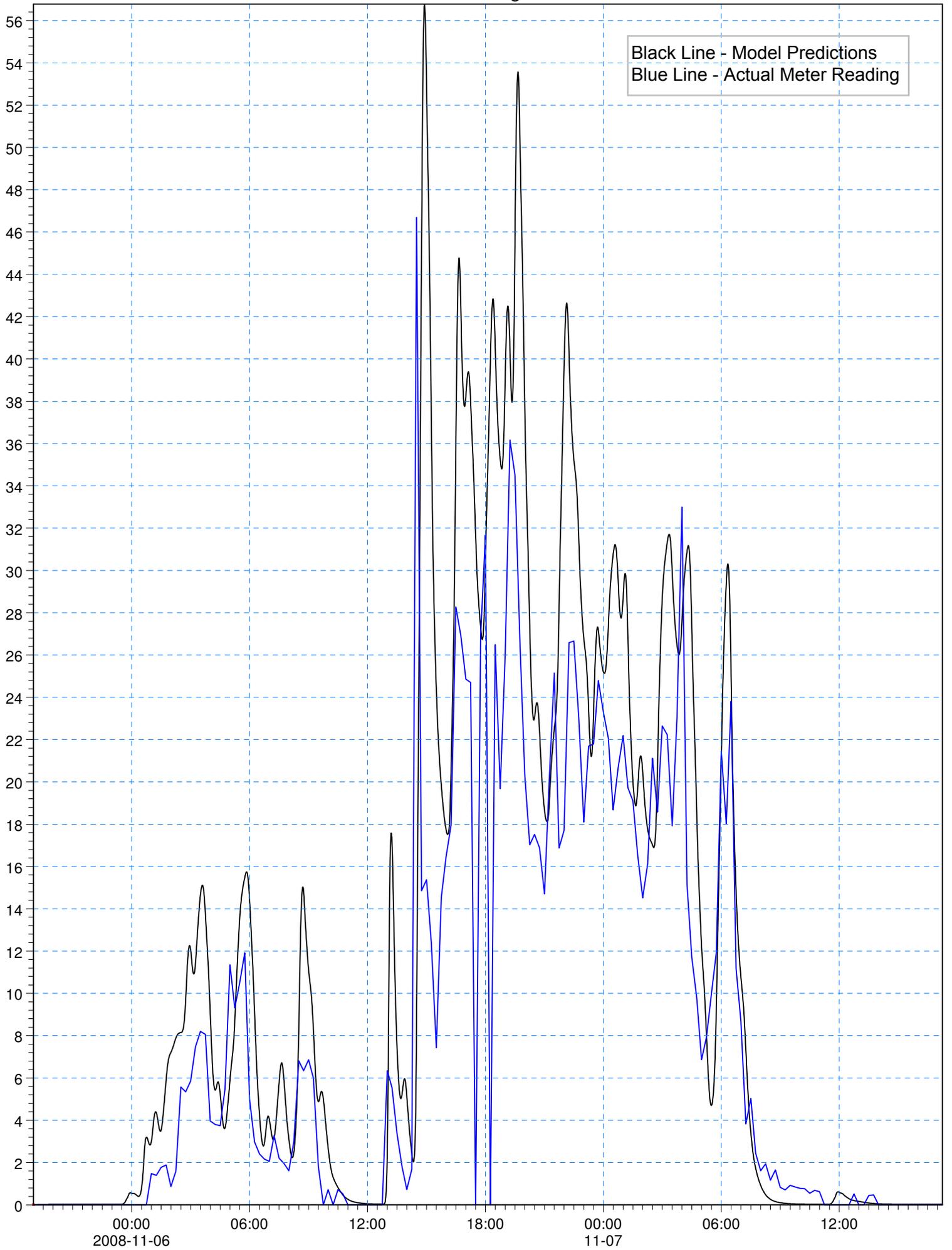


Sources: Esri, DeLorme, HERE, USGS, Intermap, increment P Corp., NRCAN, Esri Japan, METI, Esri China (Hong Kong), Esri (Thailand), TomTom

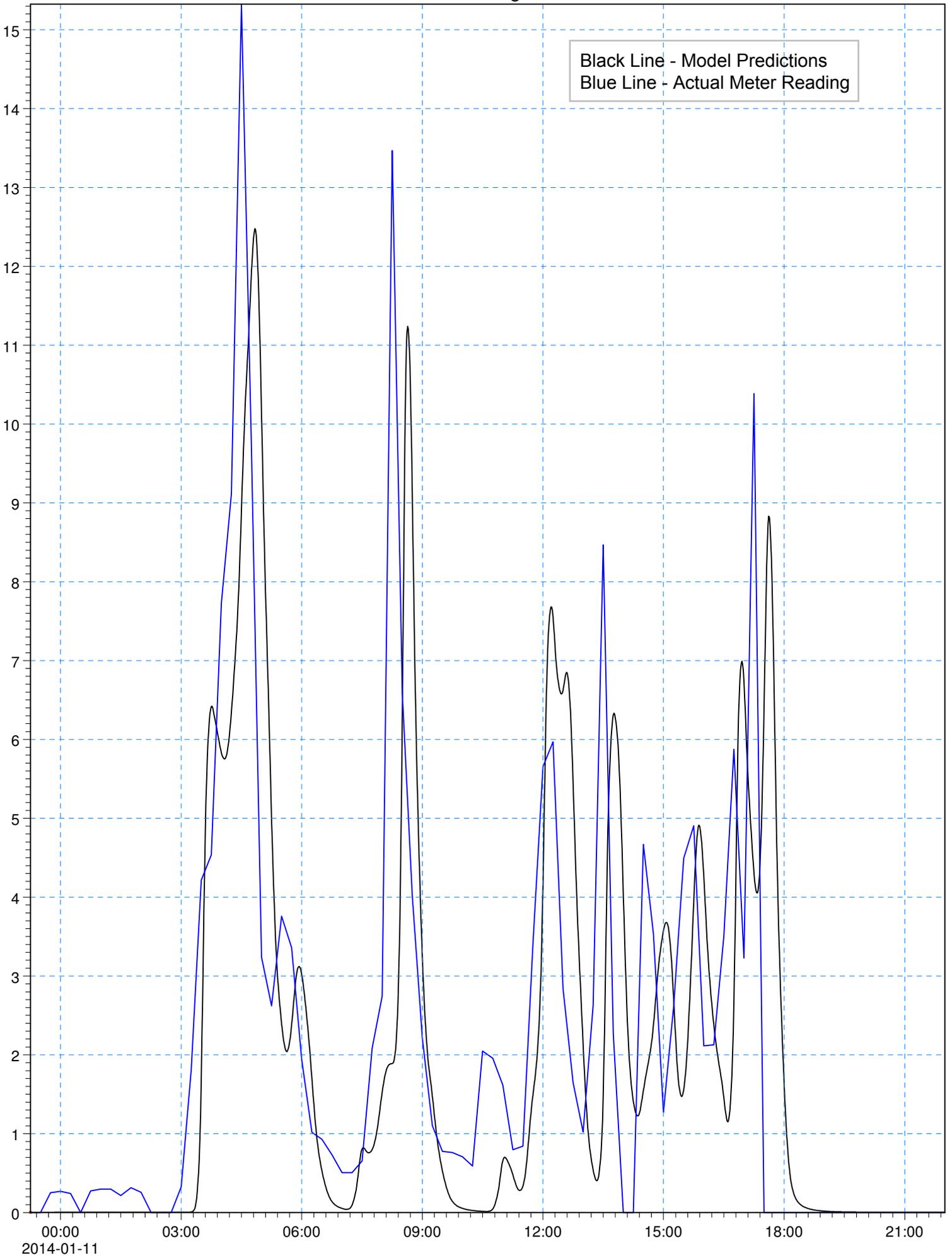
6260436 (6.71) [ft^3/s]  
Flow(cfs) [ft^3/s]

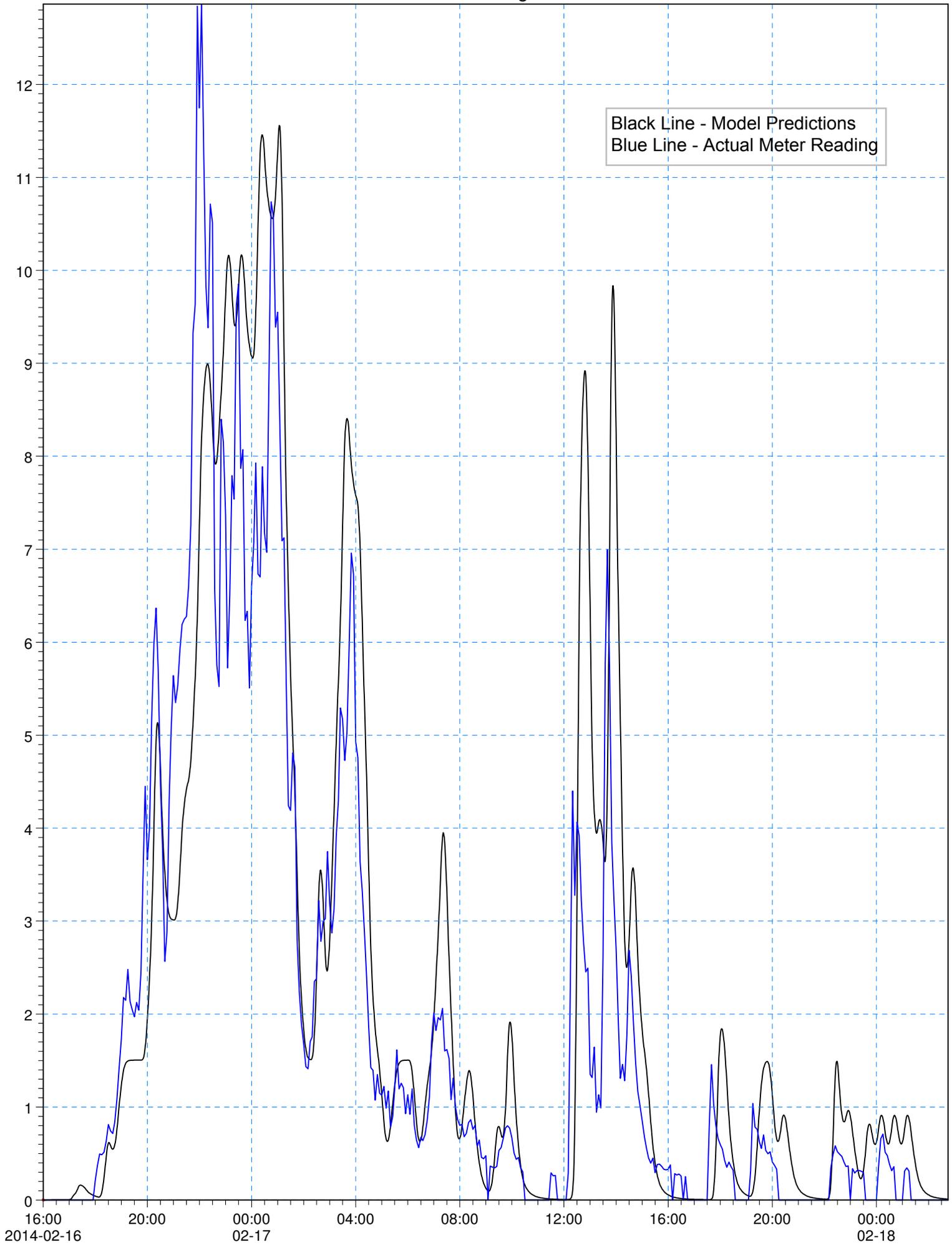
# Discharge

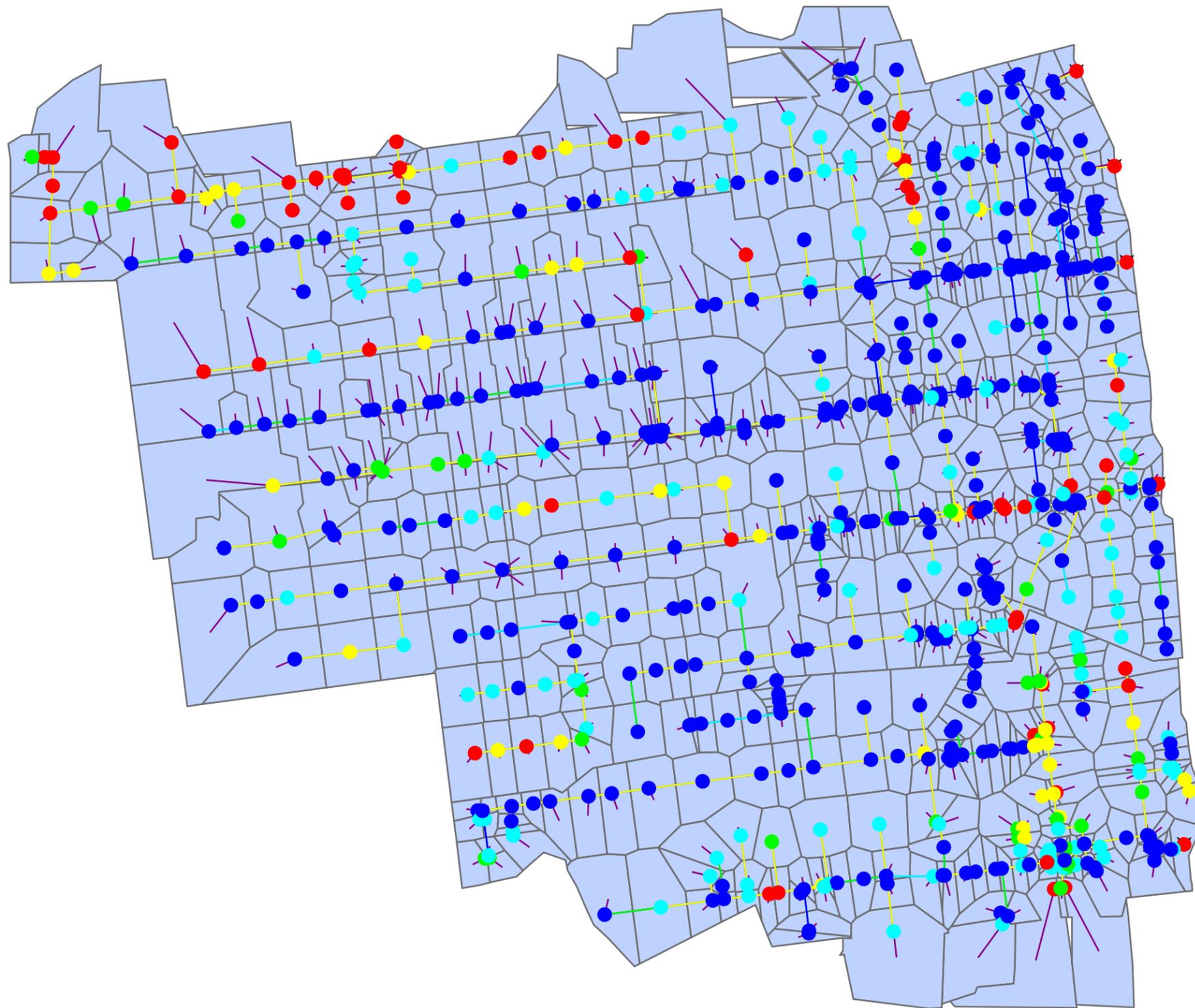
Figure 5



Black Line - Model Predictions  
Blue Line - Actual Meter Reading







**Legend**

**Max. Node Flood**

- less than 3 ft
- -3 ft to -1 ft
- -1 ft to 0 ft
- 0 ft to 1 ft
- greater than 1 ft

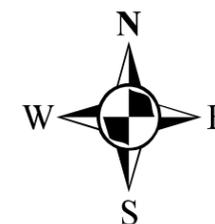
**Max. Pipe Filling**

- less than 50%
- 50% to 75%
- 75% to 100%
- 100% to 200%
- greater than 200%



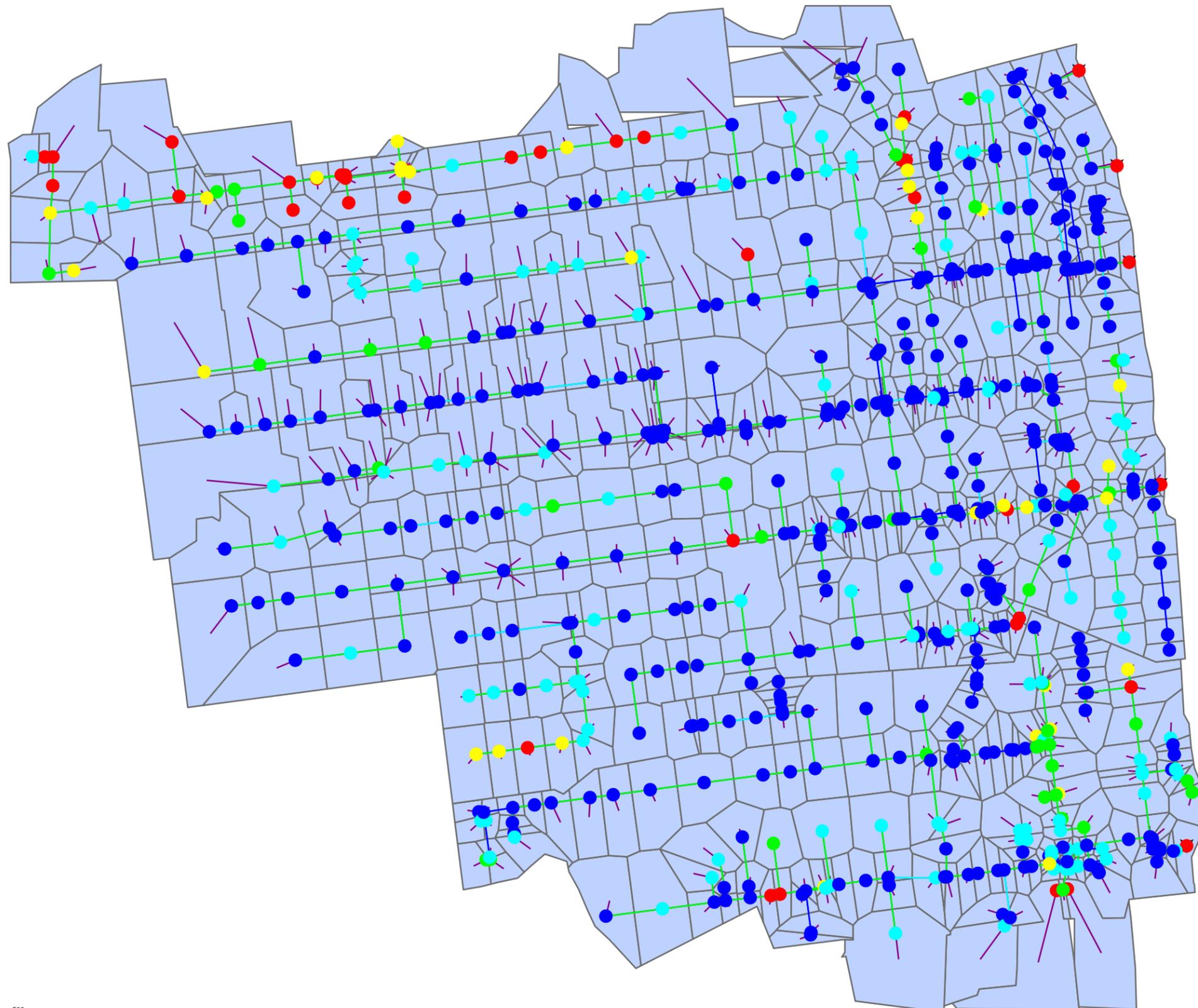
**Notes:**

Node Flood is the water level relative to the rim elevation. For example, -3 ft is 3 ft below the rim.  
 Pipe Filling is the percentage full of the pipe. Pipes greater than 100% full are running under pressure.  
 Values shown are the maximum value during the event.



Drawn By:	
Date:	
Approved:	
Scale:	1:9,720

**Figure 8**  
 100-Year Type 1A, 24-Hour Event  
 Current Development Conditions



**Legend**

**Max. Node Flood**

- less than 3 ft
- -3 ft o -1 ft
- -1 ft to 0 ft
- 0 ft to 1 ft
- greater than 1 ft

**Max. Pipe Filling**

- less than 50%
- 50% to 75%
- 75% to 100%
- 100% to 200%
- greater than 200%

0 70 140 280 420 560 Meters

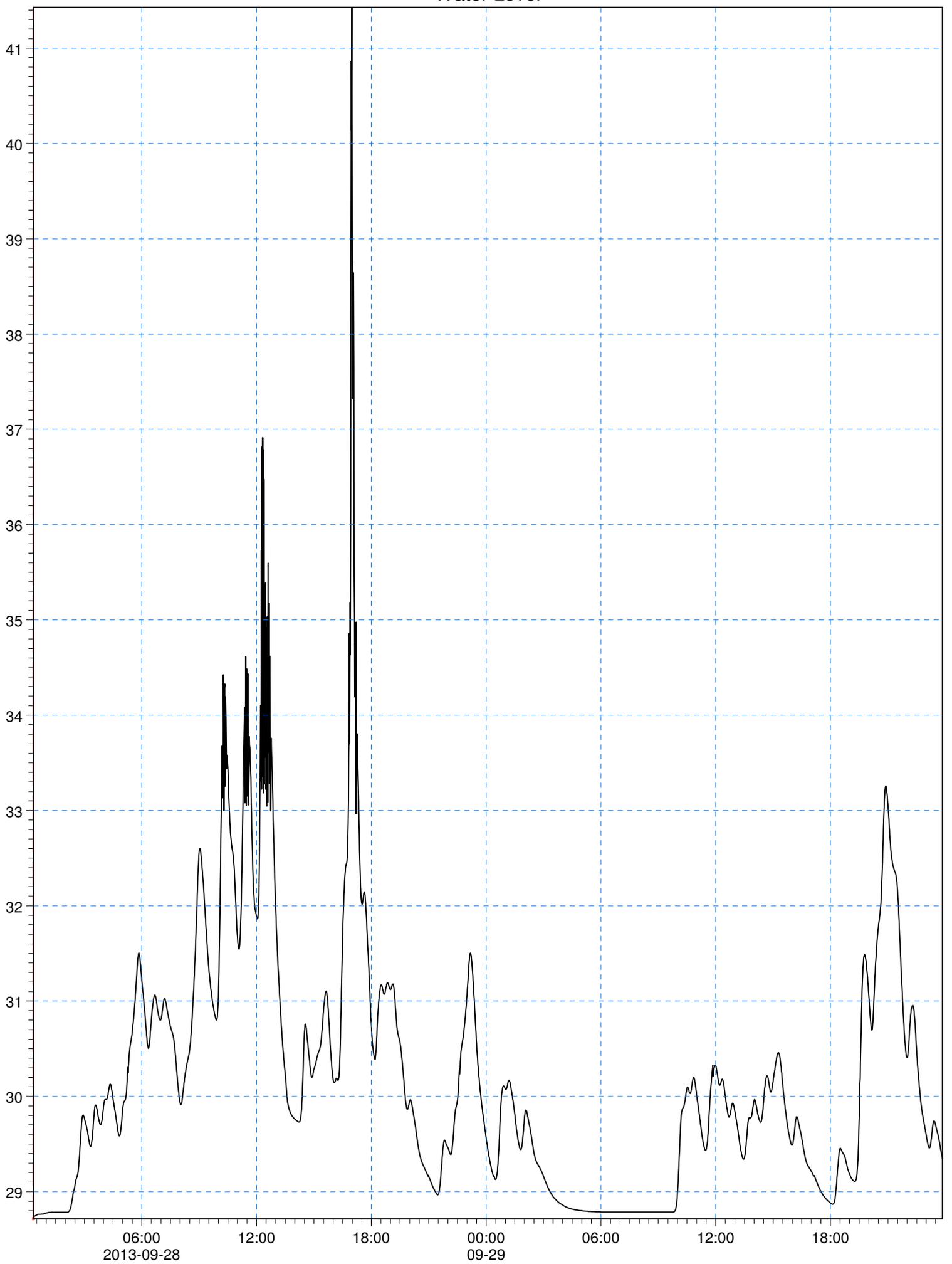
**Figure 9.**  
**9/28/13 Event**  
**Current Development Conditions**

**Notes:**

Node Flood is the water level relative to the rim elevation. For example, -3 ft is 3 ft below the rim.  
 Pipe Filling is the percentage full of the pipe. Pipes greater than 100% full are running under pressure.  
 Values shown are the maximum value during the event.



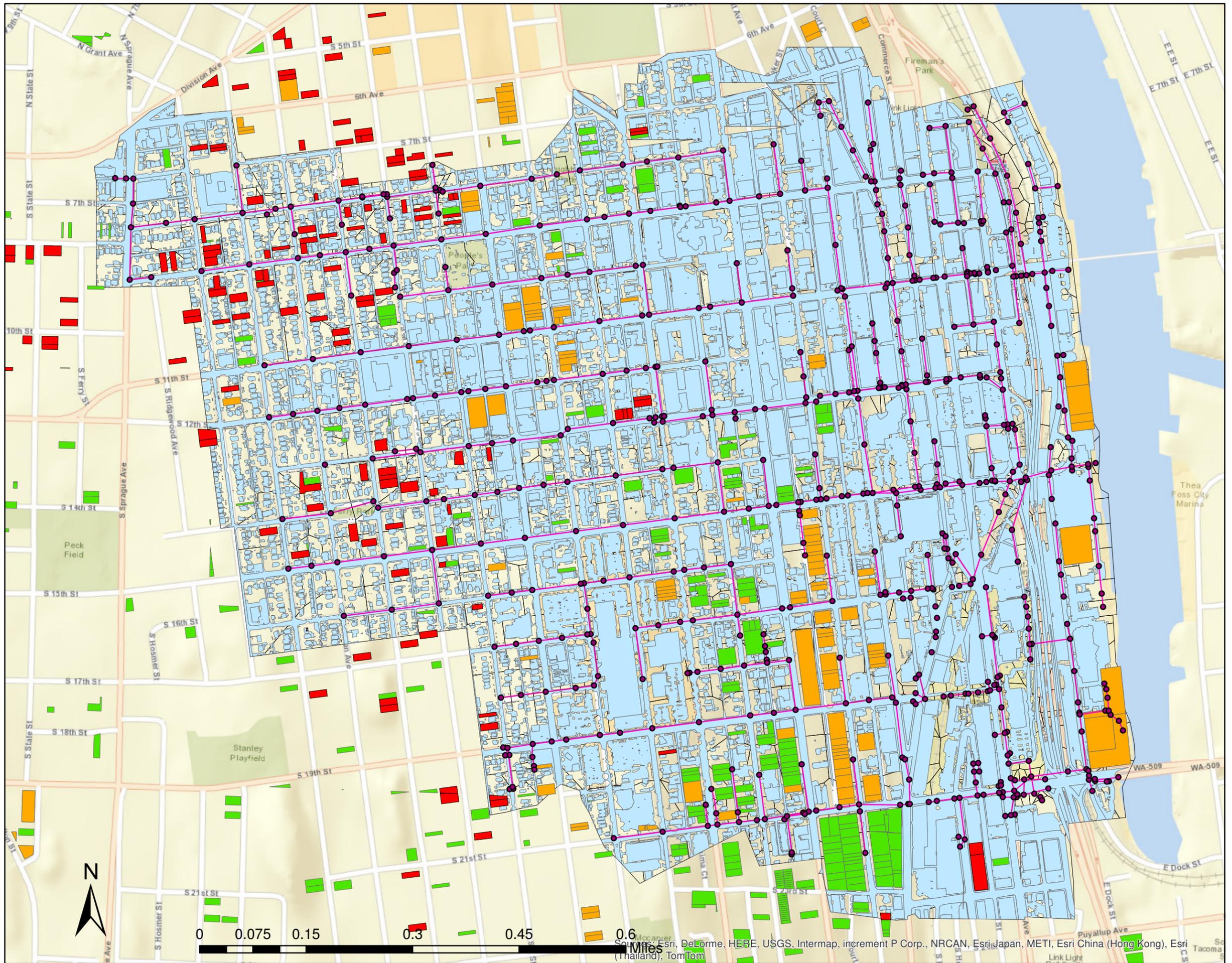
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Date:	
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**Figure 11.**  
**Existing Impervious and**  
**Vacant/Underutilized Parcels**

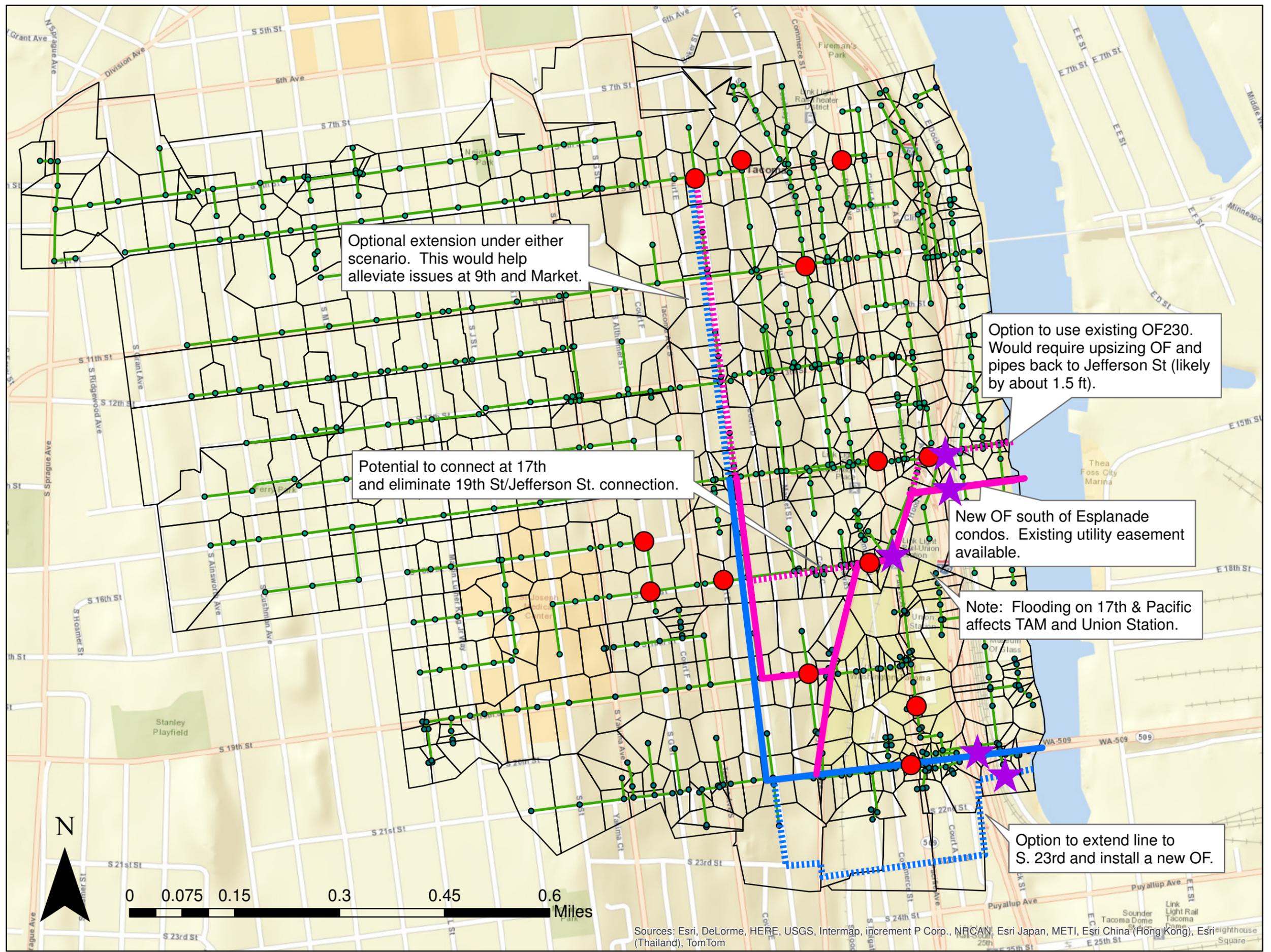
**Legend**

- Underutilized Parcels
- Vacant Residential
- Vacant Commercial\_FS05-6
- Vacant Commercial
- Existing Impervious



**Figure 12.**  
**North and South Diversion**  
**Alternatives**

-  Directional Drill Location
-  Known Flooding Areas
-  North Diversion
-  North Diversion- Alternate
-  South Diversion
-  South Diversion- Alternate

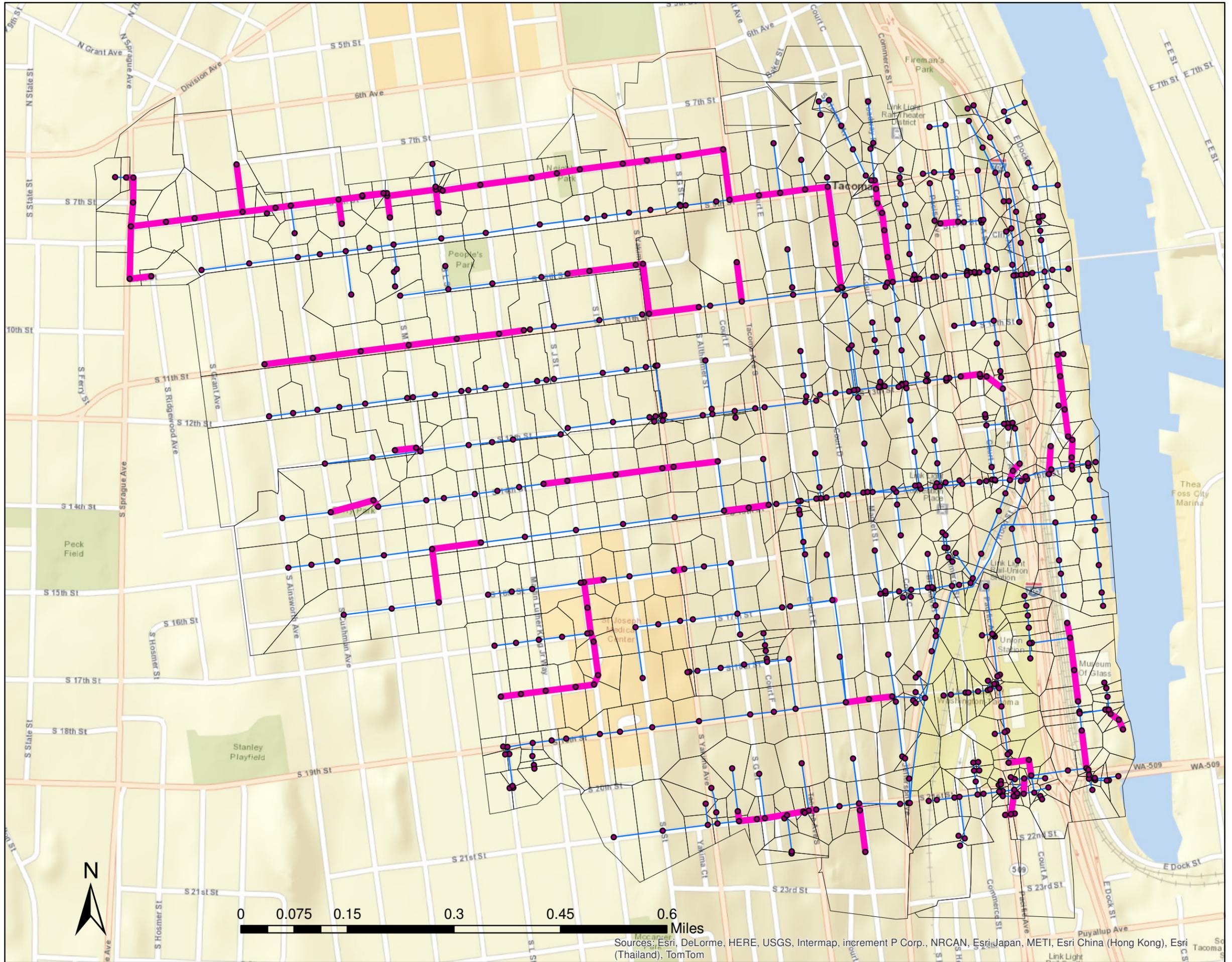


Sources: Esri, DeLorme, HERE, USGS, Intermap, increment P Corp., NRCAN, Esri Japan, METI, Esri China (Hong Kong), Esri (Thailand), TomTom

**Figure 13.**  
**Upsized Pipes**

**Legend**  
**Upsized\_100yr**  
**Diff**

- No Change
- Upsized (up to 2 ft diameter)



Sources: Esri, DeLorme, HERE, USGS, Intermap, increment P Corp., NRCAN, Esri Japan, METI, Esri China (Hong Kong), Esri (Thailand), TomTom

## Legend

### Max. Node Flood

- less than 3 ft
- -3 ft to -1 ft
- -1 ft to 0 ft
- 0 ft to 1 ft
- more than 1 ft

### Max. Pipe Filling

- less than 50%
- 50% to 75%
- 75% to 100%
- 100% to 200%
- greater than 200%

0 80 160 320 480 640 Meters

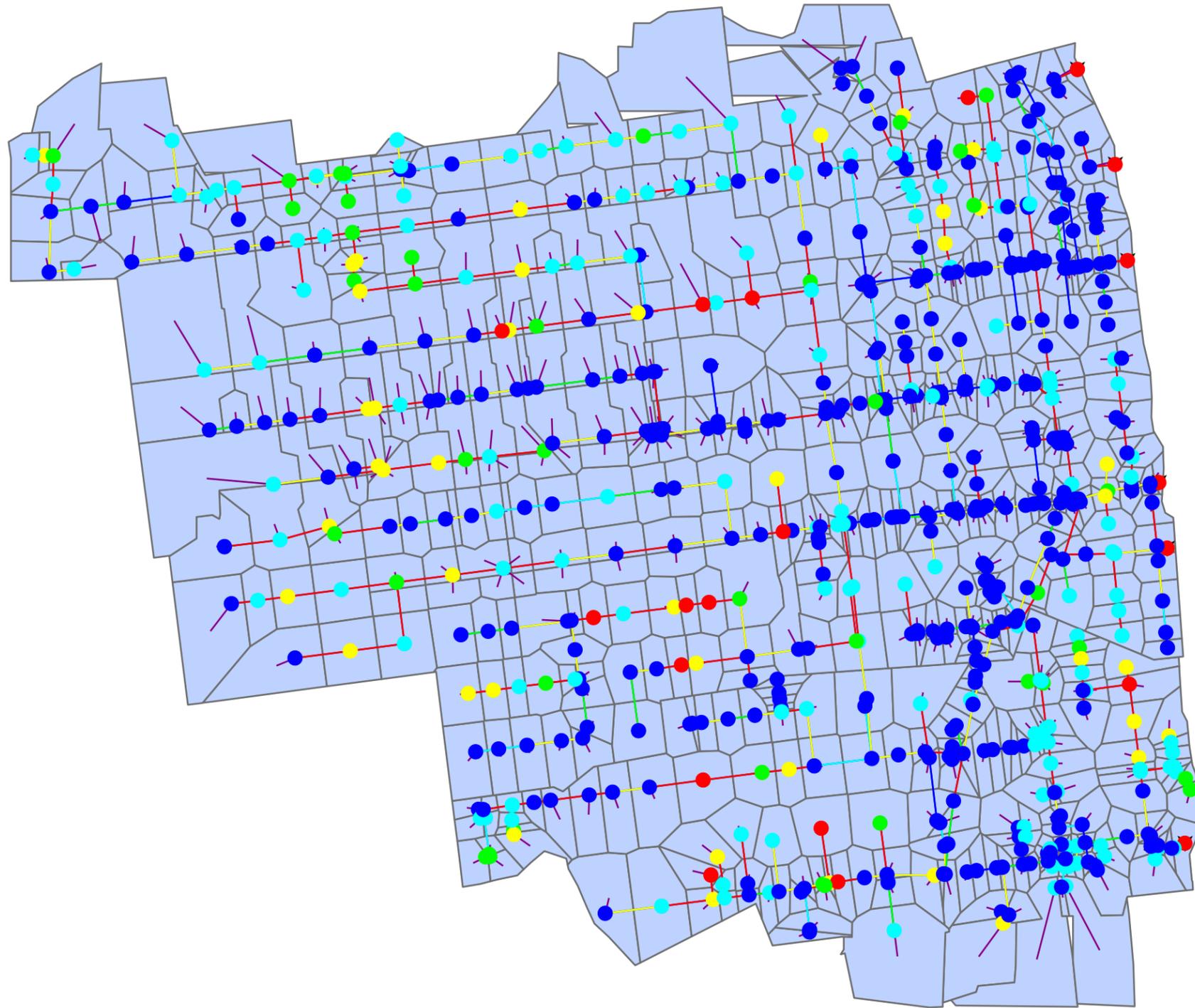
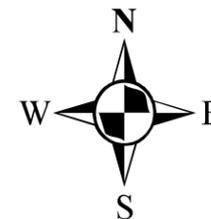


Figure 14  
6/23/13 Event (NE Tacoma RG)  
Future Development (Dev A Scenario)

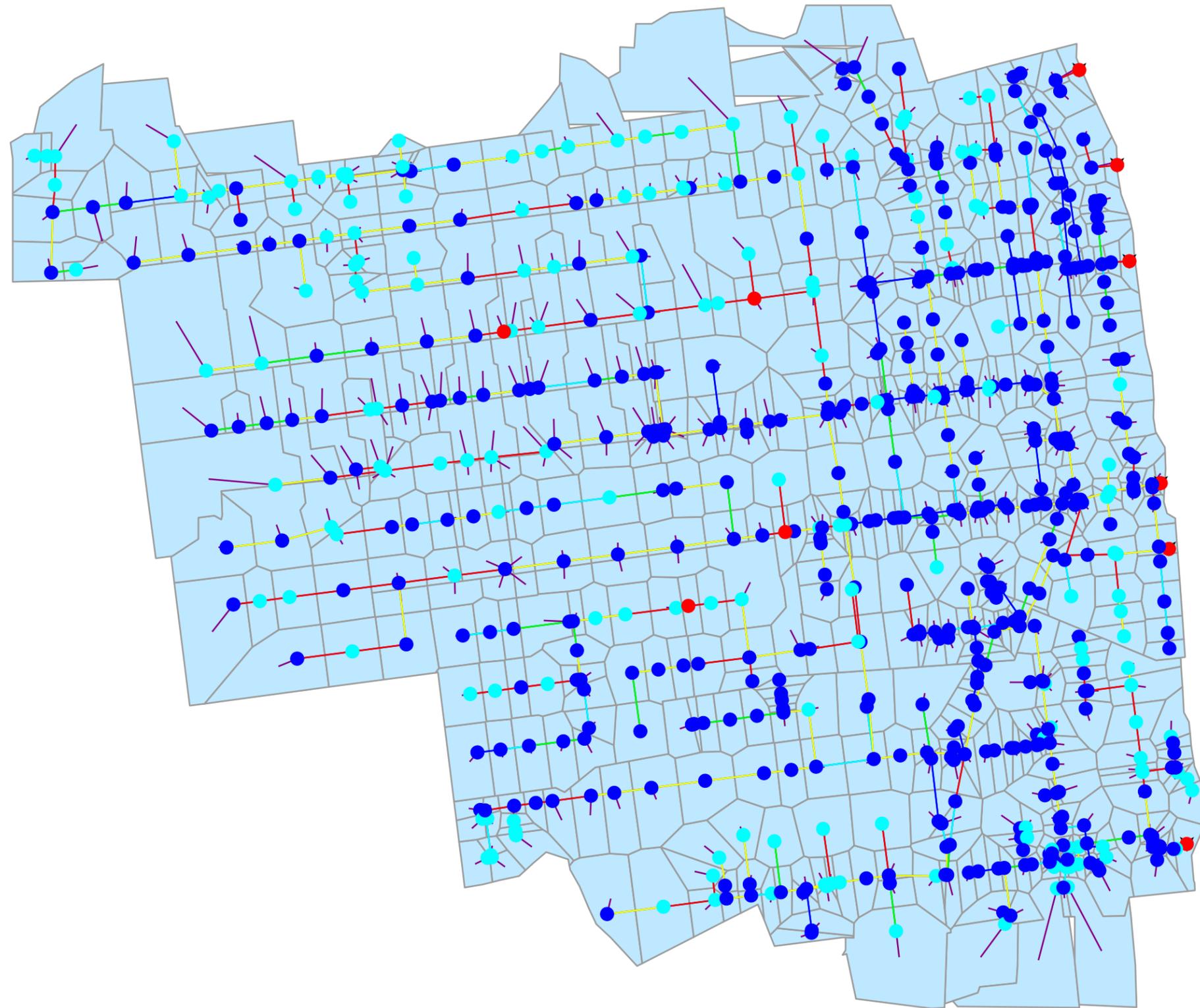
#### Notes:

Node Flood is the water level relative to the rim elevation. For example, -3 ft is 3 ft below the rim.  
Pipe Filling is the percentage full of the pipe. Pipes greater than 100% full are running under pressure.  
Values shown are the maximum value during the event.



**MIKE**  
**URBAN**

Drawn By:	
Date:	
Approved:	
Scale:	1:10,090



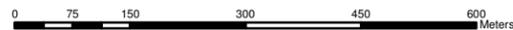
**Legend**

**Max. Node Flood**

- less than 3 ft
- -3 ft to -1 ft
- -1 ft to 0 ft
- 0 ft to 1 ft
- more than 1 ft

**Max. Pipe Filling**

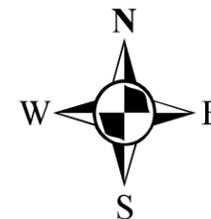
- less than 50%
- 50% to 75%
- 75% to 100%
- 100% to 200%
- more than 200%



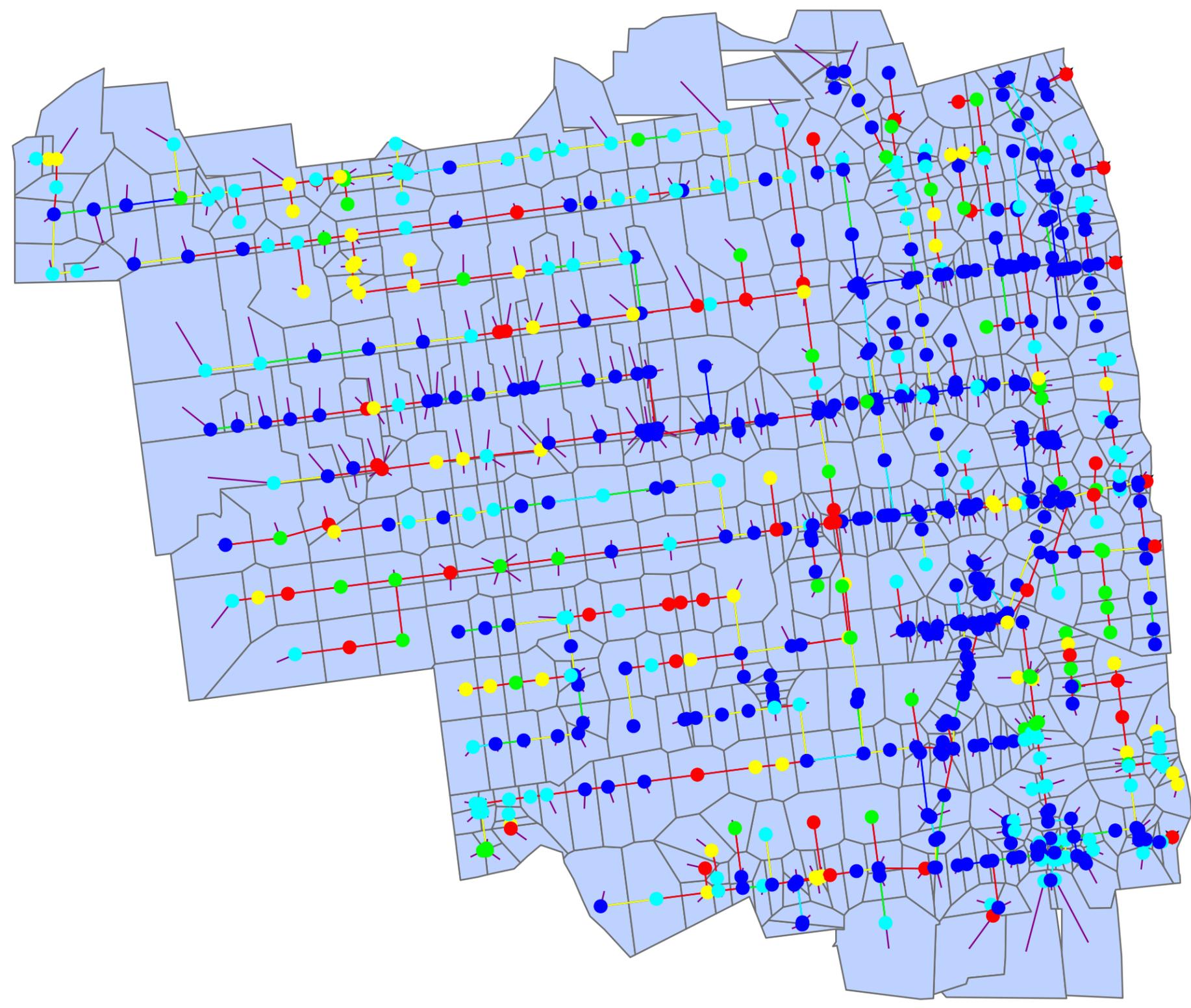
**Figure 15**  
**100-Year, Type 1A, 24-Hour Event**  
**Future Development (Dev B Scenario)**

**Notes:**

Node Flood is the water level relative to the rim elevation. For example, -3 ft is 3 ft below the rim.  
 Pipe Filling is the percentage full of the pipe. Pipes greater than 100% full are running under pressure.  
 Values shown are the maximum value during the event.



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Date:	
Approved:	
Scale:	1:9,350



**Legend**

**Max. Node Flood**

- less than 3 ft
- -3 ft to -1 ft
- -1 ft to 0 ft
- 0 ft to 1 ft
- more than 1 ft

**Max. Pipe Filling**

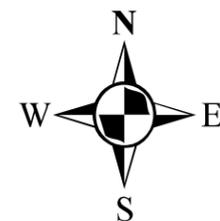
- less than 50%
- 50% to 75%
- 75% to 100%
- 100% to 200%
- more than 200%



Figure 16  
6/23/13 Event  
Future Development (Dev B Scenario)

Notes:

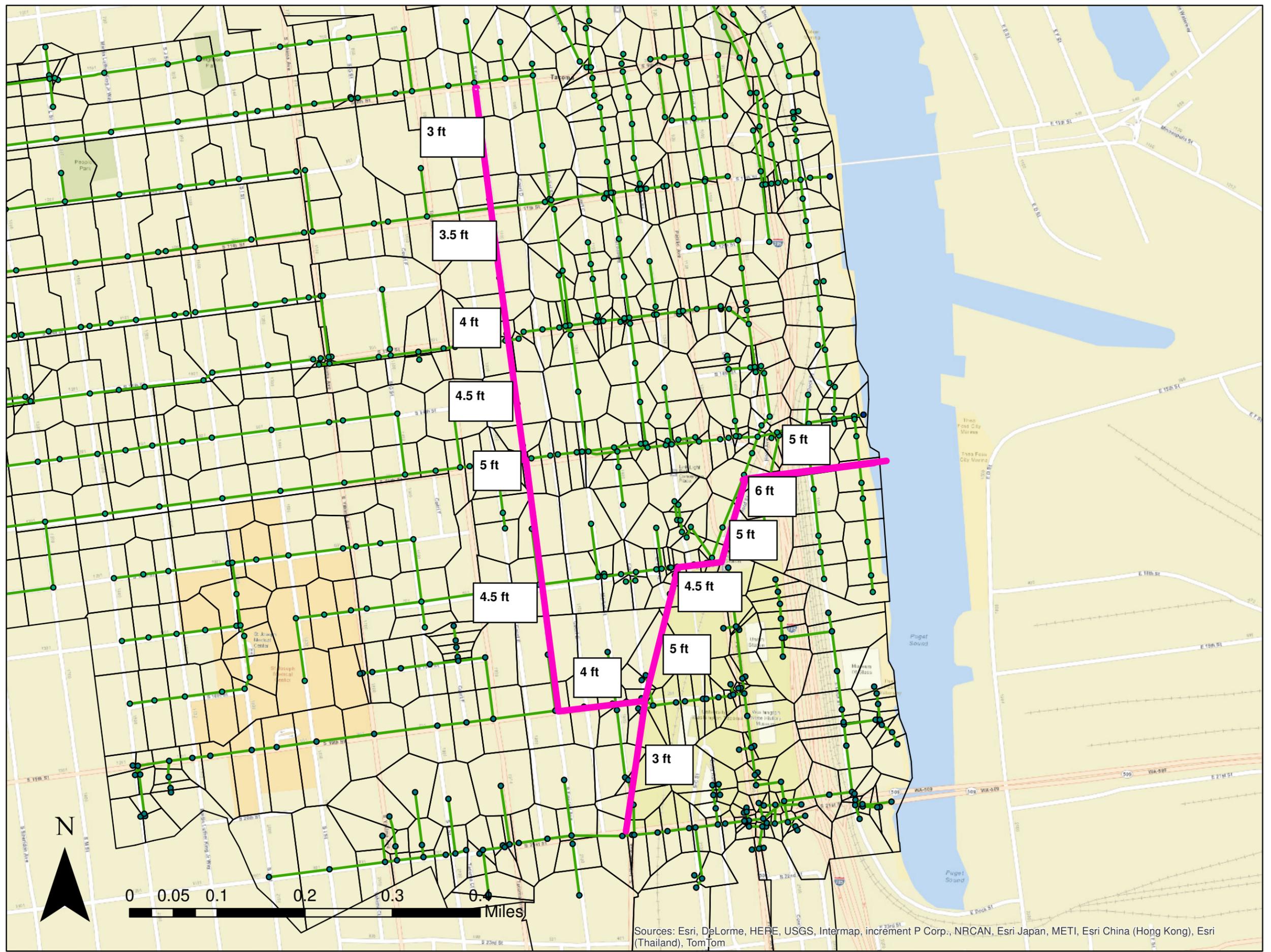
Node Flood is the water level relative to the rim elevation. For example, -3 ft is 3 ft below the rim.  
Pipe Filling is the percentage full of the pipe. Pipes greater than 100% full are running under pressure.  
Values shown are the maximum value during the event.



Drawn By:	
Date:	
Approved:	
Scale:	1:9,350

**Figure 17.**  
**Final Pipe Sizing**  
**DevB, 06/23/13 Event**

Numbers shown are  
approximate trunk main sizes.



Sources: Esri, DeLorme, HERE, USGS, Intermap, increment P Corp., NRCAN, Esri Japan, METI, Esri China (Hong Kong), Esri (Thailand), TomTom

# **APPENDIX A. WATER QUALITY INFORMATION**

This section describes the water quality data and water quality treatment devices in the basins. The evaluation of capacity, condition, and water quality data in relation to other areas of the City is outside of the scope of this Plan and as such the condition and water quality information is meant only to provide the framework for future City-wide evaluations.

## **A.1 THEA FOSS WATERWAY MONITORING DATA**

Both FS-05 and FS-06 discharge to the Thea Foss Waterway which underwent a Superfund cleanup at a cost of \$105 million to remove contaminated sediment. When the waterway sediment remediation projects were completed, the majority of the sediment surface had no, or very low concentrations of contaminants present since the surface was either dredged to clean sediments or covered with new, clean capping materials. It was anticipated that ongoing source contributions to the waterway would cause concentrations of contaminants to increase gradually.

Since stormwater is one of the potential sources, the City has been implementing a comprehensive monitoring and source control strategy in the Foss Waterway Watershed since 2001. A summary of the quality of these basins compared to other five monitored Thea Foss basins is provided below. Additional information about the water quality of these basins is provided in the Thea Foss and Wheeler-Osgood Waterways 2013 Source Control and Water Year 2013 Stormwater Monitoring Report (Tacoma 2014).

### **A.1.a FS-05**

Total suspended solids (TSS), lead, zinc, PAHs (phenanthrene, pyrene, and indeno(1,2,3-c,d)pyrene) and bis(2-ethylhexyl)phthalate (DEHP) show a statistically significant improvement in FS-05 stormwater quality from 2001 to present with an estimated 65% reduction for TSS, 66% for total lead, 30% for total zinc, 94-97% reduction for each of the three index PAHs (phenanthrene, pyrene, and indeno(1,2,3-cd)pyrene), and 81% for DEHP in the 12 year period (see Table 3-6, Tacoma 2014).

- Stormwater – Moderately lower TSS, but moderately higher DEHP concentrations compared to other Foss outfalls when evaluating the 12 year monitoring record (see Table 3-4, Tacoma 2014).
- Stormwater Sediment – Outfall results show moderately higher mercury compared to other sediment trap locations in the Foss outfalls (see Table 3-5, Tacoma 2014) when evaluating the entire 12 year monitoring record. Upline sediment traps show possible areas of concern for mercury, phthalates and PCBs.

Ongoing source tracing activities are currently occurring in the basin for PCBs, PAHs, and phthalates. Some of the sources have been identified and are currently awaiting cleanups on private property.

### **A.1.b FS-06**

TSS, lead, zinc, DEHP, and PAHs have all shown a statistically significant improvement in stormwater quality from 2001 to present (see Table 3-6 in Tacoma 2014). TSS shows an estimated 63% reduction over 12 years, lead at 61%, zinc at 41%, DEHP at 88% and PAHS (both light and heavy PAH fractions) at 94-96% reductions.

- Stormwater – Moderately higher zinc and significantly higher lead and DEHP as compared to other Foss outfalls when evaluating the 12 year monitoring record (see Table 3-4, Tacoma 2014). Pyrene is also moderately elevated when looking at only the last two years of data.
- Stormwater Sediment – Slightly higher lead compared to other sediment trap locations (see Table 3-5A) in the Foss basins when evaluating the entire 12 year monitoring record.

## **A.2 EXISTING/PLANNED TREATMENT UNITS**

Public water quality treatment devices (existing and planned) in the FS-05 and FS-06 basins are listed below.

- FS-05: The Pacific Avenue Streetscape project added Silva cells, 14 rain gardens, and a StormFilter to treat stormwater in 2013. This project treats approximately 6.26 acres of the FS-05 basin.
- FS-05: Construction of the 'A' Street regional treatment system is expected to start in mid-2014. This project will construct an underground treatment vault with Baysaver treatment units sized to treat the water quality design storm for the 34-acre tributary area.
- FS-06: A modified bioretention facility will provide regional treatment for stormwater runoff discharged from 42 acres of the FS-06 drainage basin in Tacoma's downtown area. The project was bid in February 2014 and construction is expected to begin in late spring of 2014.

In addition, private onsite stormwater treatment devices are located within the FS-05 and FS-06 boundaries. Locations of these private treatment devices are shown on Figure A.1. As future development/redevelopment occurs in these basins, additional treatment devices are anticipated.



# **APPENDIX B. SEATTLE PUBLIC UTILITIES – STORMWATER MANUAL CONVEYANCE MODELING GUIDANCE**

Where:  $T_t$  = Travel time (minutes)  
 $L$  = Length of flow across a given segment (feet)  
 $V$  = average velocity (ft/sec) across the land segment.

$$V = k_r \sqrt{S_o} \tag{5}$$

Where:  $k_r$  = Velocity factor (Table 6.4)  
 $S_o$  = Slope of flow path (feet/feet).

**Table 6.4. Coefficients for Average Velocity Equation ( $k_r$ ).**

Land Cover	Velocity Factor ( $k_r$ )
Forest with Heavy Ground Cover and Meadow	2.5
Grass, Pasture, and Lawns	7.0
Nearly Bare Ground	10.1
Grassed Swale or Channel	15.0
Paved Areas	20.0

## 6.4 Single-Event Rainfall-Runoff Methods

### 6.4.1 Introduction

Single-event models simulate rainfall-runoff processes for a single storm, typically 2 hours to 72 hours in length and usually of a specified exceedance probability. Because the primary interest is the flood hydrograph, calculation of evapotranspiration, soil moisture changes between storms, and base flow processes are typically not needed. This is in contrast to continuous rainfall-runoff models (Section 6.5) where multi-decade precipitation and evaporation time series are used as input to produce a corresponding multi-decade time series of runoff.

Precipitation input to single-event models can include either historic data recorded from a rain gage or a synthetic design storm hyetograph. This section describes the use of both types of precipitation input.

### 6.4.2 Design Storm Hyetographs

Design storm hyetographs were developed using noteworthy storms that were recorded by the City of Seattle gauging network. Statistical analyses were conducted for the storm characteristics and dimensionless design storms were developed for short, intermediate, and long-duration storm events (MGS 2004). The short, intermediate, and long-duration design storms can be scaled to any site-specific recurrence interval using precipitation magnitudes at the 2-hour, 6-hour, and 24-hour duration.

The choice of a design storm hyetograph depends on the characteristics of the watershed being analyzed. Short duration storms have high intensity but limited

volume, and are generally the controlling storm for small watersheds with little hydrologic storage. Intermediate and long duration storms have progressively lower intensities but higher volume. These types of storms often control the design of conveyance facilities in larger watersheds and control the design of volume-dependent structures.

Table 6.5 summarizes the applicability of the four City design storms. If multiple storm types are listed for a particular application, then all applicable storm types should be considered candidates and used in the hydrologic model. The candidate storm that produces the most severe hydrologic loading and most conservative design is then adopted as the design storm. Note that this table does not override the modeling requirements for specific facilities outlined in Chapters 2, 4, and 5 or Table 6.1. Table 6.5 is for general guidance and applicability only.

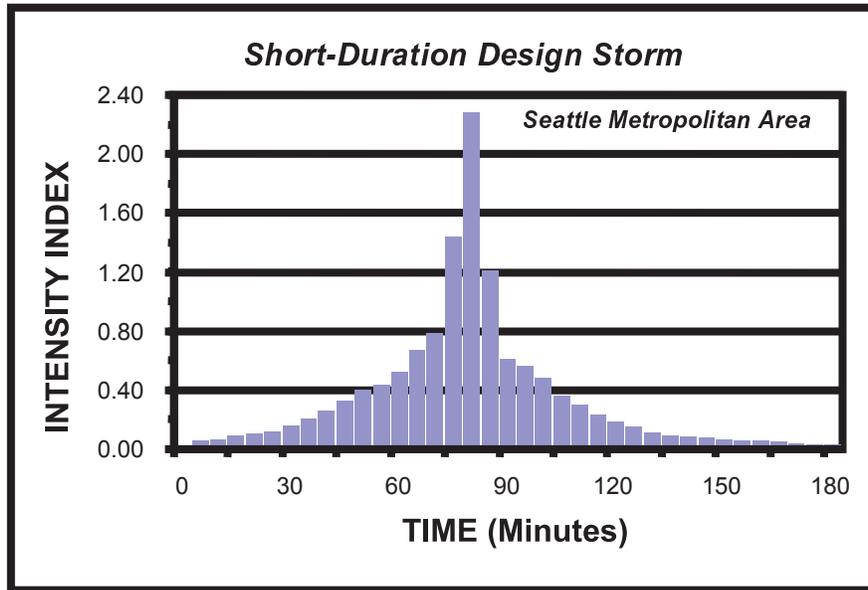
**Table 6.5. Applicability of Storm Types for Hydrologic Design Applications.**

Storm Type	Design Applicability	Total Storm Duration	Precipitation from SPU Rain Gages
Short	Conveyance Flow Control	3 Hours	2 Hours
Intermediate	Conveyance Flow Control	18 Hours	6 Hour
Seattle 24-Hour	Volume Based BMPs	24 Hour	24 Hour
Long – Front Loaded	Flow Control	64 Hours	24 Hour
Long – Back Loaded	Flow Control	64 Hours	24 Hour

#### 6.4.2.1 Short Duration Storm (3-hour)

Short duration storms typically occur in the late spring through early-fall seasons and are characterized by high intensities for short periods of time over localized areas. These types of storms can produce high rates of runoff and flash flooding in urban areas.

Short-duration design storms are used for design situations where peak discharge is of primary interest. Common applications include design of storm drains, ditches, and culverts, and other hydraulic structures for conveyance. The short-duration storm hyetograph is 3 hours in duration. The storm temporal pattern is shown in Figure 6.2 as a dimensionless unit hyetograph. Tabular values for this hyetograph are listed in Appendix B. The total storm precipitation is 1.06 times the 2-hour precipitation amount.



**Figure 6.2. Dimensionless Short-Duration (3-Hour) Design Storm, Seattle Metropolitan Area.**

Use the following steps to utilize this storm in hydrologic analyses.

**Step 1** – Obtain the 2-hour precipitation amount for the recurrence interval of interest for the watershed (refer to Appendix C and the DPD-SPU Stormwater webpage for modeling resources).

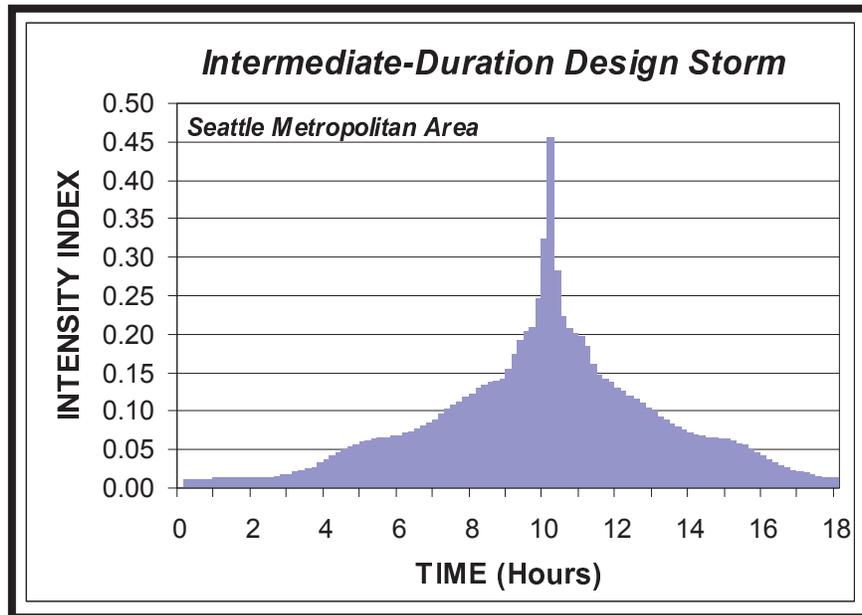
**Step 2** – Multiply the 5-minute incremental ordinates of the dimensionless short-duration design storm (Appendix B, Table B-1) by the 2-hour value from Step 1. Note that the resulting storm has a duration of 3 hours and total storm amount will be 1.06 times the volume of the 2-hour precipitation (refer to the DPD-SPU Stormwater webpage for modeling resources).

**Step 3** – Input the resulting storm hyetograph into the hydrologic model. The resultant incremental precipitation ordinates have units of inches. To obtain the corresponding intensities (inch/hour), multiply the precipitation increments by 12.

**6.4.2.2 Intermediate Duration Storm (18-hour)**

Intermediate-duration design storms are used in design applications where both peak discharge and runoff volume are important considerations and there is a need for a runoff hydrograph. Intermediate duration storms generally occur in the fall to early winter.

The intermediate-duration storm hyetograph is 18 hours in duration. The storm temporal pattern is shown in Figure 6.3 as a dimensionless unit hyetograph. Tabular values for this hyetograph are listed in Appendix B. The total storm precipitation is 1.51 times the 6-hour precipitation amount.



**Figure 6.3. Dimensionless Intermediate-Duration (18-Hour) Design Storm, Seattle Metropolitan Area.**

The following steps describe how to utilize this storm in hydrologic analyses.

**Step 1** – Obtain the 6-hour precipitation amount for the recurrence interval of interest for the watershed (refer to Appendix C and the DPD-SPU Stormwater webpage for modeling resources).

**Step 2** – Multiply the 10-minute incremental ordinates of the dimensionless intermediate-duration design storm (Appendix B, Table B-2) by the 6-hour value from Step 1. Note that the resulting storm has a duration of 18 hours and the total storm amount will be 1.51 times the volume of the 6-hour precipitation (refer to the DPD-SPU Stormwater webpage for modeling resources).

**Step 3** – Input the resulting storm hyetograph into the hydrologic model. The resultant incremental precipitation ordinates have units of inches. To obtain the corresponding intensities (inch/hour), multiply the precipitation increments by 6.

#### 6.4.2.3 Long Duration Storm (64-hour)

Long-duration design storms are primarily used in design of stormwater detention facilities and other projects where runoff volume is a primary consideration. Long duration storms occur primarily in the late fall into early spring.

Two long-duration dimensionless design storms are provided: a front-loaded design storm with the highest intensities at the beginning of the storm; and a back-loaded storm with the higher intensities nearer the end of the storm period. Characteristics of the front-loaded design storm have been observed more frequently, and this storm would be expected to produce more “typical” runoff

conditions. The back-loaded storm occurs less often and is typically a more conservative event for drainage control facility design.

The long-duration storm hyetographs are 64 hours in duration. The storm temporal patterns for the front loaded and back loaded storms are shown in Figures 6.4 and 6.5 respectively. Tabular values for these storms are listed in Appendix B. The total storm precipitation is 1.29 times the 24-hour precipitation amount for both the front and back loaded long-duration storm.

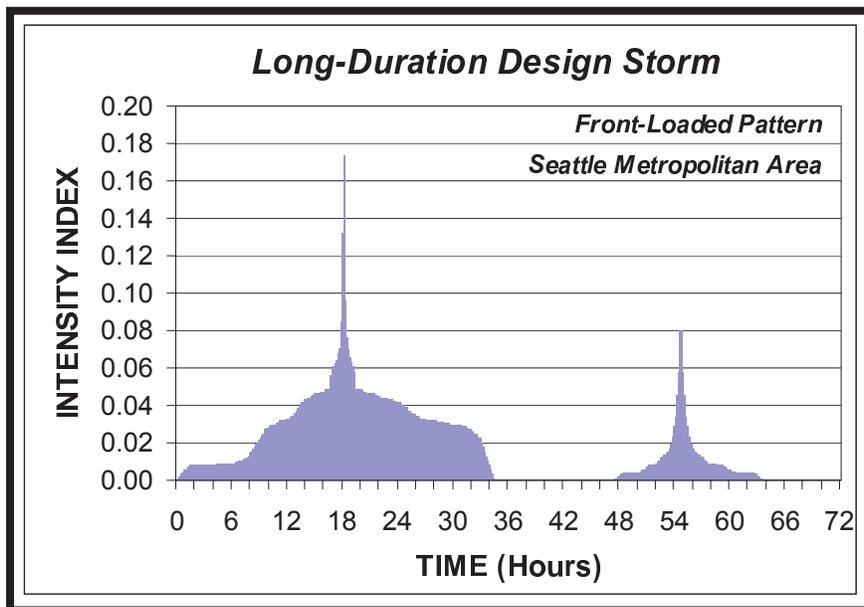


Figure 6.4. Dimensionless Front-Loaded Long-Duration (64-Hour) Design Storm for the Seattle Metropolitan Area.

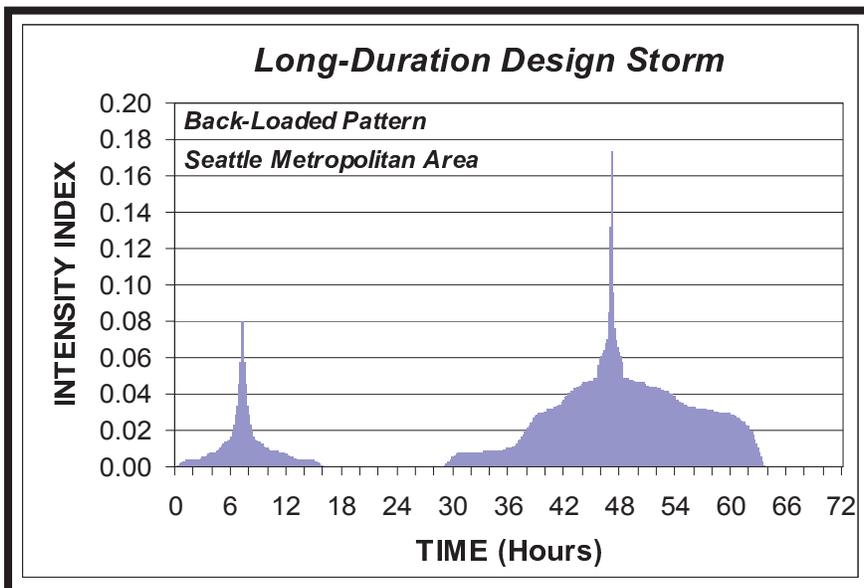


Figure 6.5. Dimensionless Back-Loaded Long-Duration (64-Hour) Design Storm for the Seattle Metropolitan Area.

Use the following steps to utilize the long-duration storm in hydrologic analyses.

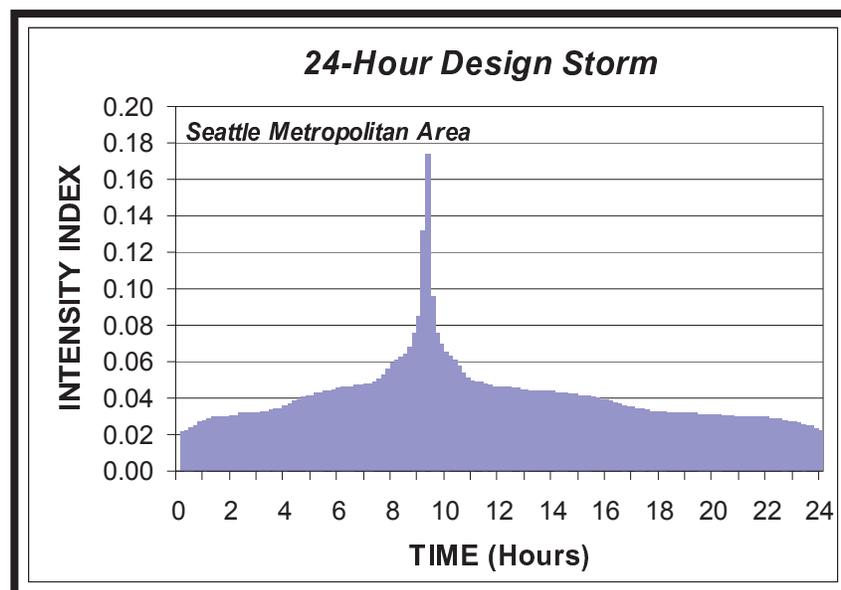
**Step 1** – Obtain the 24-hour precipitation amount for the recurrence interval of interest for the watershed (refer to Appendix C and the DPD-SPU Stormwater webpage for modeling resources).

**Step 2** – Multiply the 10 minute incremental ordinates of the dimensionless long-duration design storm (Appendix B, Table B-3 or B-4) by the 24-hour value from Step 1. Note that the resulting storm has a duration of 64 hours and total storm amount 1.29 times the volume of the 6-hour precipitation (refer to the DPD-SPU Stormwater webpage for modeling resources).

**Step 3** – Input the resulting storm hyetograph into the hydrologic model. The resultant incremental precipitation ordinates have units of inches. To obtain the corresponding intensities (inches/hours), multiply the precipitation increments by 6.

#### 6.4.2.4 24-Hour Dimensionless Design Storm

Some specific stormwater applications require or allow the use of a 24-hour design storm. To meet this need, the 24-hour dimensionless design storm was developed based on the maximum 24-hour period of precipitation within the long-duration design storm. It should be noted that the 24-hour dimensionless design storm has the same temporal shape and ordinates as the period of maximum 24-hour precipitation within the front-loaded and back-loaded long-duration dimensionless design storms. The City of Seattle 24-hour design storm is shown in Figure 6.6.



**Figure 6.6. Dimensionless 24-Hour Design Storm for Seattle Metropolitan Area.**

Use the following steps to utilize the long-duration storm in hydrologic analyses.

**Step 1** – Obtain the 24-hour precipitation amount for the recurrence interval of interest (refer to Appendix C and the DPD-SPU Stormwater webpage for modeling resources).

**Step 2** – Multiply the 10 minute incremental ordinates of the dimensionless long-duration design storm (Appendix B, Table B-5) by the 24-hour value from Step 1 (refer to the DPD-SPU Stormwater webpage for modeling resources).

**Step 3** – Input the resulting storm hyetograph into the hydrologic model. The resultant incremental precipitation ordinates have units of inches. To obtain the corresponding intensities (inches/hours), multiply the precipitation increments by 6.

#### 6.4.2.5 **City of Seattle Precipitation**

National Oceanic and Atmospheric Administration (NOAA) Atlas 2 precipitation-frequency (isopluvial) maps published in the early 1970s have historically been used in hydrologic analysis and design. These maps are replaced in this manual by precipitation magnitude-frequency estimates more specific to the City of Seattle.

These estimates are based on a regional analysis using data from the SPU Rain Gage Network and gages from the NOAA national cooperative gaging network in western Washington. The most recent analysis included data from 1940 to 2003. Figure 6.7 shows the SPU Rain Gage Network as of 2003 and Appendix C gives the precipitation data based on this network. Changes to the SPU Rain Gage Network have been made since 2003 and updates to data analysis are ongoing. Updated information can be obtained from the SPU Rain Gage Network Data Steward or the DPD-SPU Stormwater webpage for modeling resources.

#### 6.4.3 **Use of Historic Storms in Analysis**

This section includes a catalog of the storms used to derive the design storm patterns described in the previous section. These historic storms can be used in rainfall runoff models to aid in the design process by replicating past floods. For example, an engineer could use the historic storms to demonstrate that a proposed conveyance system design would have adequate capacity to pass a large historic flood that occurred in the watershed. The storms could also be used for calibrating the hydrologic model to recorded flow data. Use of these historic storms to confirm a facility design is recommended but is not required for the design of stormwater facilities.

Tables 6.6, 6.7, and 6.8 summarize historic storms recorded at City gauges for durations of 2 hours, 6 hours, and 24 hours respectively. Included in each table is the date when the storm ended, storm recurrence interval, and total precipitation for the duration of interest. The gage locations are shown in Figure 6.7. Electronic data for each storm is available in tabular form from Seattle Public Utilities (refer to the DPD-SPU Stormwater webpage for modeling resources).



Figure 6.7. City Rain Gage Network Stations.

**Table 6.6. Catalog of Short-Duration (2-Hour) Storms at City Rain Gages.**

Station ID	Station Name	Storm End-Date	Storm Recurrence Interval (years)	2-hour Precipitation (in)
45-S002	Mathews Beach Pump Stn	06/14/1978	16	0.86
45-S003	UW Hydraulics Lab	11/03/1978	10	0.79
45-S009	Woodland Park Zoo	08/17/1980	20	0.89
45-S008	Ballard Locks	08/28/1980	20	0.89
45-S002	Mathews Beach Pump Stn	05/29/1985	7	0.74
45-S014	West Seattle High School	10/26/1986	15	0.85
45-S020	TT Minor Elementary	10/04/1990	18	0.88
45-S009	Woodland Park Zoo	08/09/1991	6	0.72
45-S008	Ballard Locks	09/23/1992	45	1.02
45-S003	UW Hydraulics Lab	11/23/1997	9	0.77
45-S011	Metro-KC Denny Regulating	02/17/1998	14	0.84
45-S016	Metro-KC E Marginal Way	07/15/2001	6	0.71
45-S012	Catherine Blaine Jr	08/23/2001	14	0.84
45-S020	TT Minor Elementary	05/28/2002	4	0.83
45-S009	Woodland Park Zoo	09/03/2002	10	0.79
45-S004	Maple Leaf Reservoir	10/20/2003	18	0.88
45-S003	UW Hydraulics Lab	12/14/2006	13	0.83

**Table 6.7. Catalog of Intermediate-Duration (6-Hour) Storms at City Rain Gages.**

Station ID	Station Name	Storm End Date	Storm Recurrence Interval (years)	6-Hour Precip (inches)
45-S016	Metro-KC E Marginal Way	9/22/1978	32	1.61
45-S001	Haller Lake Shop	11/04/1978	70	1.74
45-S003	UW Hydraulics Lab	12/03/1982	92	1.82
45-S001	Haller Lake Shop	09/05/1984	5	1.21
45-S020	TT Minor Elementary	01/18/1986	>100	2.27
45-S010	Rainier Ave Elementary	01/09/1990	88	1.83
45-S003	UW Hydraulics Lab	12/29/1996	16	1.45
45-S004	Maple Leaf Reservoir	06/24/1999	7	1.28
45-S004	Maple Leaf Reservoir	10/20/2003	>100	1.96
45-S003	UW Hydraulics Lab	12/14/2006	36	1.62

**Table 6.8. Catalog of Long-Duration (24-Hour) Storms at City Rain Gages.**

Station ID	Station Name	Storm End Date	Storm Recurrence Interval (years)	24-Hour Precip (inches)
45-S008	Ballard Locks	12/17/1979	4	2.40
45-S009	Woodland Park Zoo	10/06/1981	24	3.07
45-S004	Maple Leaf Reservoir	11/01/1984	3	2.11
45-S001	Haller Lake Shop	01/18/1986	96	3.69
45-S016	Metro-KC E Marginal Way	11/23/1986	9	2.70
45-S003	UW Hydraulics Lab	11/24/1990	17	2.91
45-S002	Mathews Beach Pump Stn	04/04/1991	4	2.15
45-S020	TT Minor Elementary	02/08/1996	>100	5.07
45-S020	TT Minor Elementary	04/23/1996	8	2.56
45-S003	UW Hydraulics Lab	03/18/1997	7	2.53
45-S004	Maple Leaf Reservoir	11/25/1998	11	2.68
45-S010	Rainier Ave Elementary	11/14/2001	34	3.31
45-S004	Maple Leaf Reservoir	10/20/2003	>100	4.05

When using historic data from the City rain gage network for model calibration, storms should be selected from stations as close as possible to the center of the watershed tributary to the project site. This will help ensure that the recorded data is representative of precipitation that fell in the watershed for storm of interest. In general, the shorter duration storms typically have smaller areal coverage and greater spatial variability than the longer duration storms. Thus, greater simulation errors would be expected if gage data outside the watershed is used to simulate short duration storms.

#### 6.4.4 Watershed Characterization

Prior to conducting any detailed stormwater runoff calculations, the overall relationship between the proposed project site and upstream and downstream off-site areas must be considered. The general hydrologic characteristics of the project site dictate the amount of runoff that will occur and where stormwater facilities can be placed. It is important to identify the stormwater destination point, including potential backwater effects. Drainage patterns and contributing areas can be determined from preliminary surveys of the area, available topographic contour maps, and Seattle Public Utilities drainage system maps. Note that the drainage systems often cross topographic divides within the City of Seattle. Maps can be obtained through the Seattle Public Utilities' GIS map counter (<http://www.ci.seattle.wa.us/GIS/docs/mapctr.htm>).

##### 6.4.4.1 Calculation of Total Impervious Area

Impervious coverage for proposed development must be estimated. Impervious coverage of streets, sidewalks, hard surface trails, etc., shall be taken from plans

# **APPENDIX C. SEATTLE PUBLIC UTILITIES – HISTORIC RAINFALL EVALUATION**

## **Appendix C - Precipitation Magnitude-Frequency Estimates for SPU Rain Gage Locations (up to 2003 data only)**

This appendix contains adapted text and excerpted tables and figures from *Analysis of Precipitation-Frequency and Storm Characteristics for the City of Seattle* (MGS Engineering Consultants, Inc. for Seattle Public Utilities, December 2003). The analysis presented here is from rain gage data ending in 2003. Analysis of data from later years was not available at the time of publication of the 2008 Directors' Rules. Updated information may be obtained from the SPU Rain Gage Network Data Steward as it becomes available.

The results of homogeneity analyses indicate that at-site mean values for precipitation do not vary across the Seattle Metropolitan Area for durations of 3 hours and less. Accordingly, one set of intensity-duration-frequency (IDF) curves can be developed that are applicable to the Seattle Metropolitan Area. Table 5 and Figures 15a and 15b provide precipitation intensities and IDF curves representative of the Seattle Metropolitan Area for durations from 5 to 180 minutes.

**Table 5. Intensity-Duration-Frequency Values for Durations from 5-Minutes through 180-Minutes for Selected Recurrence Intervals for the Seattle Metropolitan Area.**

DURATION (minutes)	PRECIPITATION INTENSITIES (in/hr)							
	RECURRENCE INTERVAL (Years)							
	6-Month	2-YR	5-YR	10-YR	20-YR	25-YR	50-YR	100-YR
5	1.01	1.60	2.08	2.45	2.92	3.08	3.61	4.20
6	0.92	1.45	1.87	2.21	2.62	2.76	3.23	3.75
8	0.80	1.24	1.59	1.87	2.21	2.32	2.71	3.13
10	0.71	1.10	1.40	1.64	1.93	2.03	2.36	2.72
12	0.65	1.00	1.27	1.48	1.74	1.82	2.11	2.43
15	0.58	0.88	1.12	1.30	1.52	1.60	1.84	2.11
20	0.50	0.75	0.95	1.10	1.28	1.34	1.54	1.76
25	0.45	0.67	0.84	0.97	1.12	1.18	1.35	1.53
30	0.41	0.61	0.76	0.87	1.01	1.05	1.21	1.37
35	0.38	0.56	0.69	0.80	0.92	0.96	1.10	1.24
40	0.35	0.52	0.64	0.74	0.85	0.89	1.01	1.14
45	0.33	0.49	0.60	0.69	0.79	0.83	0.94	1.06
50	0.32	0.46	0.57	0.65	0.74	0.78	0.88	0.99
55	0.30	0.44	0.54	0.61	0.70	0.73	0.83	0.94
60	0.29	0.42	0.51	0.58	0.67	0.70	0.79	0.89
65	0.28	0.40	0.49	0.56	0.64	0.66	0.75	0.84
70	0.27	0.38	0.47	0.53	0.61	0.64	0.72	0.80
80	0.25	0.36	0.43	0.49	0.56	0.59	0.66	0.74
90	0.24	0.33	0.41	0.46	0.52	0.55	0.62	0.69
100	0.22	0.32	0.38	0.43	0.49	0.51	0.58	0.64
120	0.20	0.29	0.35	0.39	0.44	0.46	0.52	0.57
140	0.19	0.26	0.32	0.36	0.40	0.42	0.47	0.52
160	0.18	0.24	0.29	0.33	0.37	0.39	0.43	0.48
180	0.17	0.23	0.27	0.31	0.35	0.36	0.40	0.45

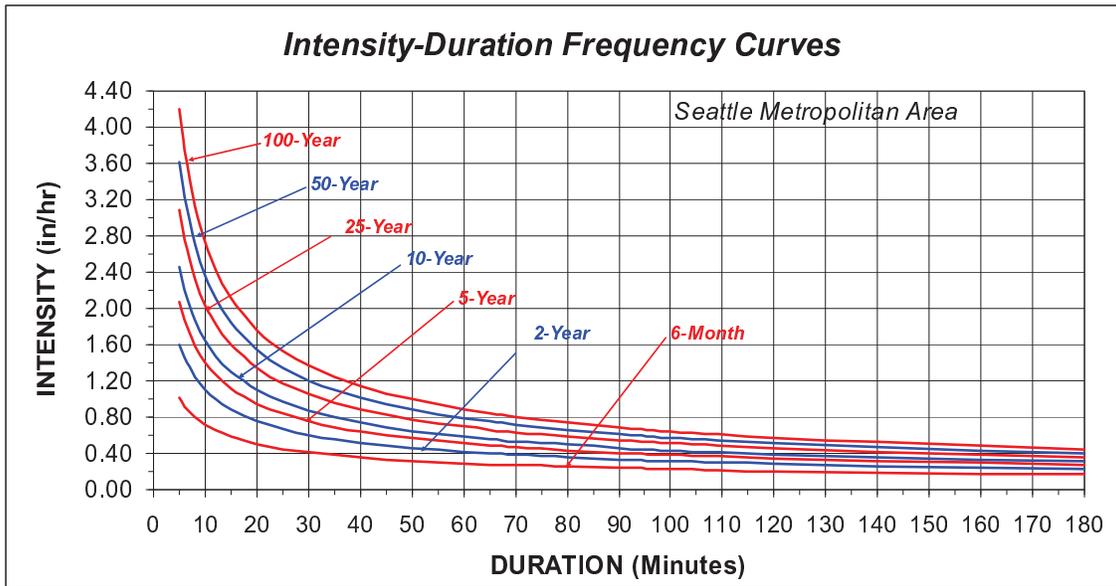


Figure 15a. Intensity-Duration-Frequency Curves for the Seattle Metropolitan Area.

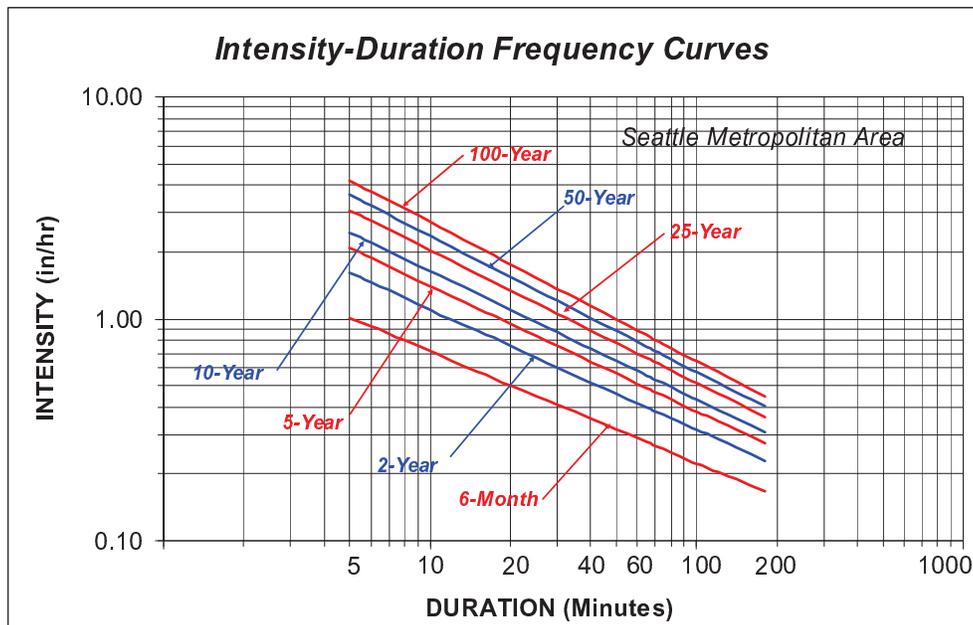


Figure 15b. Intensity-Duration-Frequency Curves for the Seattle Metropolitan Area.

The following tables and figures contain estimates of precipitation-frequency values for durations of 6 hours, 12 hours, 24 hours, 48 hours, and 7 days for locations of SPU precipitation gages (Table E-1a) in both tabular format and as magnitude-frequency curves. These precipitation values are based on estimates of the at-site mean values for the location of SPU gages (Table E-1b) based on the spatial analysis of precipitation (gridded datasets) and the applicable regional growth curves obtained from the regional frequency analyses. Corrections have been applied to provide equivalent partial duration series estimates for frequently occurring events (5 times/year, 2 times/year, once/year, 2-year, and 5-year recurrence intervals).

**Table E-1a. Listing of City of Seattle (SPU) Precipitation Gages.**

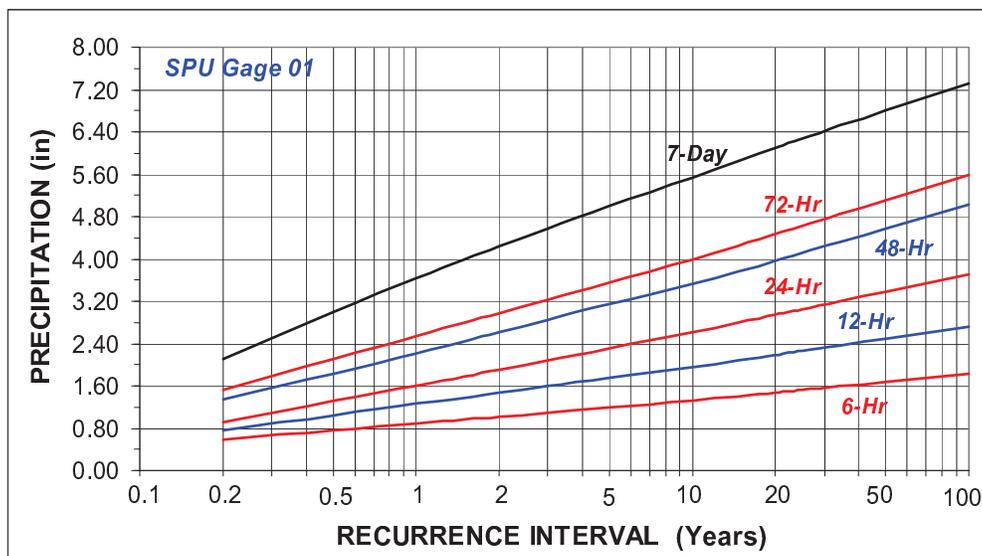
Station ID	Station Name	Latitude	Longitude	Year Start	Year End	Gage Type
45-S001	Haller Lake Shop	47.7211	122.3431	1965	2003	TB
45-S002	Mathews Beach Pump Station	47.6950	122.2731	1969	2003	TB
45-S003	UW Hydraulics Lab	47.6481	122.3081	1965	2003	TB
45-S004	Maple Leaf Reservoir	47.6900	122.3119	1965	2003	TB
45-S005	Fauntleroy Ferry Dock	47.5231	122.3919	1968	2003	TB
45-S007	Whitman Middle School	47.6961	122.3769	1965	2003	TB
45-S008	Ballard Locks	47.6650	122.3969	1965	2003	TB
45-S009	Woodland Park Zoo	47.6681	122.3539	1965	2003	TB
45-S010	Rainier Ave Elementary	47.5000	122.2600	1968	2003	TB
45-S011	Metro-KC Denny Regulating	47.6169	122.3550	1970	2003	TB
45-S012	Catherine Blaine Jr	47.6419	122.3969	1965	2003	TB
45-S014	West Seattle High School	47.5781	122.3819	1965	2003	TB
45-S015	Metro-KC Diagonal Pump	47.5619	122.3400	1965	2003	TB
45-S016	Metro-KC E Marginal Way	47.5350	122.3139	1970	2003	TB
45-S017	West Seattle Engr Shop	47.5211	122.3450	1965	2003	TB
45-S018	Hillman Engr Shop	47.5481	122.2750	1965	2003	TB
45-S020	TT Minor Elementary	47.6119	122.3069	1975	2003	TB
45-7473	Seattle Tacoma Airport	47.4500	122.3000	1965	2002	HR

**Table E-1b. Listing of At-Site Mean Values for City of Seattle (SPU) Precipitation Gages.**

At-Site Mean Values (in)							
Station ID	Station Name	6-Hr	12-Hr	24-Hr	48-Hr	72-Hr	7-Day
45-S001	Haller Lake Shop	1.00	1.44	1.87	2.56	2.91	4.10
45-S002	Mathews Beach Pump Station	1.00	1.43	1.85	2.55	2.89	4.07
45-S003	UW Hydraulics Lab	1.01	1.45	1.90	2.60	2.95	4.18
45-S004	Maple Leaf Reservoir	1.00	1.44	1.87	2.57	2.91	4.11
45-S005	Fauntleroy Ferry Dock	1.06	1.58	2.14	2.89	3.32	4.80
45-S007	Whitman Middle School	1.01	1.45	1.89	2.59	2.94	4.16
45-S008	Ballard Locks	1.03	1.50	1.99	2.71	3.08	4.41
45-S009	Woodland Park Zoo	1.01	1.45	1.89	2.59	2.94	4.16
45-S010	Rainier Ave Elementary	1.02	1.47	1.94	2.65	3.01	4.28
45-S011	Metro-KC Denny Regulating	1.01	1.46	1.91	2.61	2.97	4.21
45-S012	Catherine Blaine Jr	1.03	1.50	1.99	2.71	3.09	4.41
45-S014	West Seattle High School	1.03	1.51	2.00	2.73	3.11	4.44
45-S015	Metro-KC Diagonal Pump	1.01	1.46	1.91	2.61	2.96	4.20
45-S016	Metro-KC E Marginal Way	1.02	1.47	1.94	2.65	3.02	4.29
45-S017	West Seattle Engr Shop	1.03	1.51	2.02	2.74	3.13	4.48
45-S018	Hillman Engr Shop	1.01	1.46	1.91	2.61	2.97	4.21
45-S020	TT Minor Elementary	1.00	1.44	1.88	2.58	2.92	4.12
45-7473	Seattle Tacoma Airport	1.04	1.54	2.06	2.80	3.20	4.60

**Table E-2. Precipitation-Magnitude-Frequency Estimates for of SPU Gage 01.**

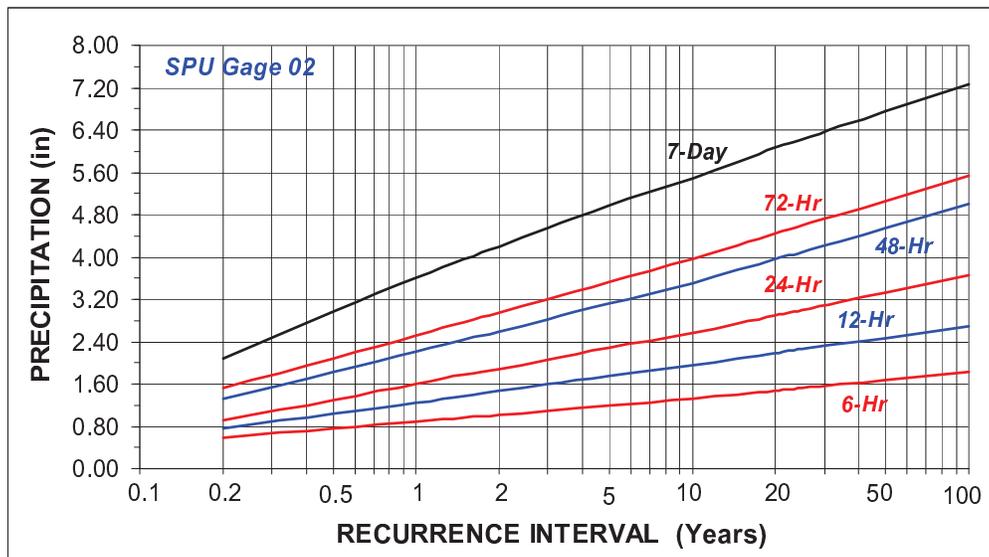
Duration (hr)	Precipitation (in)									
	Recurrence Interval (years)									
	0.2-Yr	0.5-Yr	1-Yr	2-Yr	5-Yr	10-Yr	20-Yr	25-Yr	50-Yr	100-Yr
6	0.58	0.75	0.88	1.02	1.20	1.33	1.48	1.52	1.67	1.82
12	0.76	1.05	1.26	1.47	1.76	1.96	2.19	2.27	2.49	2.72
24	0.93	1.32	1.61	1.91	2.31	2.61	2.94	3.04	3.37	3.71
48	1.34	1.84	2.22	2.61	3.14	3.53	3.97	4.11	4.56	5.02
72	1.53	2.11	2.53	2.97	3.56	3.98	4.47	4.62	5.10	5.58
168	2.11	3.00	3.62	4.23	5.01	5.53	6.10	6.28	6.81	7.32



**Figure E-2. Precipitation-Magnitude-Frequency Estimates for of SPU Gage 01.**

**Table E-3. Precipitation-Magnitude-Frequency Estimates for SPU Gage 02.**

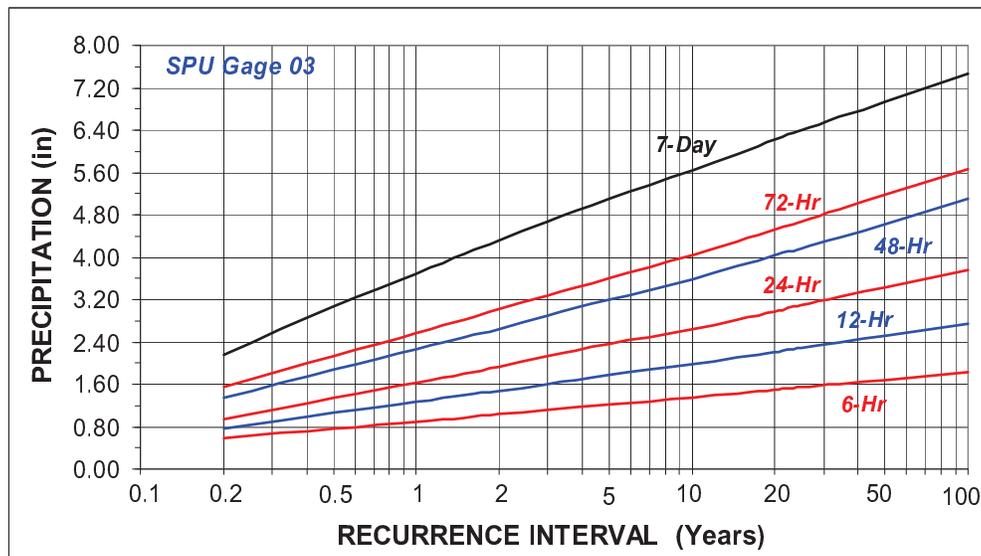
Duration (hr)	Precipitation (in)									
	Recurrence Interval (years)									
	0.2-Yr	0.5-Yr	1-Yr	2-Yr	5-Yr	10-Yr	20-Yr	25-Yr	50-Yr	100-Yr
6	0.58	0.75	0.88	1.02	1.20	1.33	1.48	1.52	1.67	1.82
12	0.76	1.04	1.25	1.46	1.75	1.95	2.18	2.25	2.48	2.70
24	0.92	1.31	1.59	1.89	2.29	2.58	2.90	3.01	3.34	3.67
48	1.33	1.83	2.21	2.60	3.13	3.51	3.95	4.10	4.55	5.00
72	1.52	2.09	2.51	2.95	3.54	3.96	4.43	4.59	5.06	5.55
168	2.09	2.98	3.60	4.20	4.97	5.49	6.06	6.23	6.76	7.27



**Figure E-3. Precipitation-Magnitude-Frequency Estimates for SPU Gage 02.**

**Table E-4. Precipitation-Magnitude-Frequency Estimates for SPU Gage 03.**

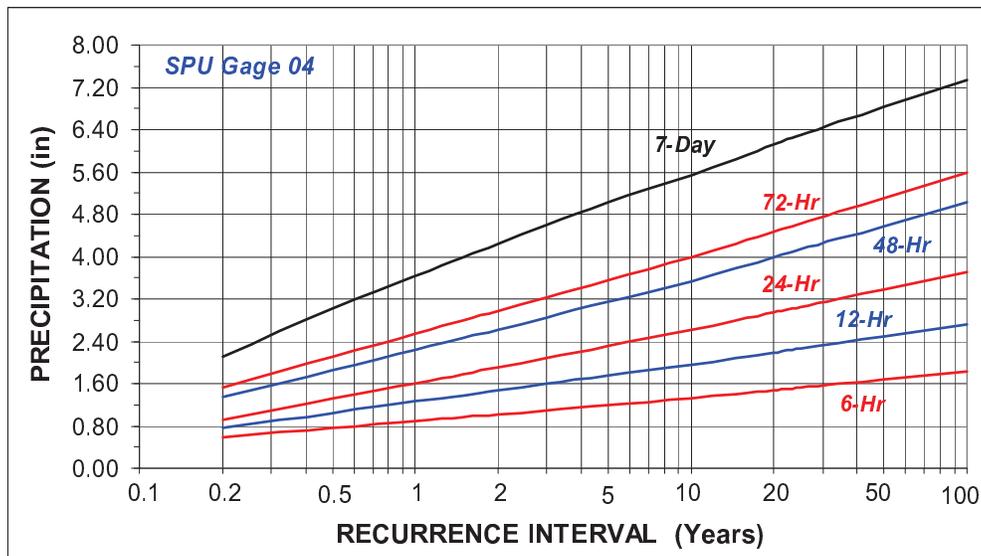
Duration (hr)	Precipitation (in)									
	Recurrence Interval (years)									
	0.2-Yr	0.5-Yr	1-Yr	2-Yr	5-Yr	10-Yr	20-Yr	25-Yr	50-Yr	100-Yr
6	0.58	0.76	0.89	1.03	1.21	1.34	1.49	1.54	1.69	1.84
12	0.77	1.06	1.27	1.48	1.77	1.97	2.21	2.28	2.51	2.74
24	0.94	1.34	1.64	1.94	2.35	2.65	2.98	3.09	3.43	3.77
48	1.36	1.87	2.25	2.65	3.19	3.58	4.03	4.18	4.63	5.10
72	1.55	2.14	2.57	3.01	3.61	4.04	4.53	4.68	5.17	5.66
168	2.15	3.06	3.69	4.32	5.10	5.64	6.22	6.40	6.94	7.47



**Figure E-4. Precipitation-Magnitude-Frequency Estimates for SPU Gage 03.**

**Table E-5. Precipitation-Magnitude-Frequency Estimates for SPU Gage 04.**

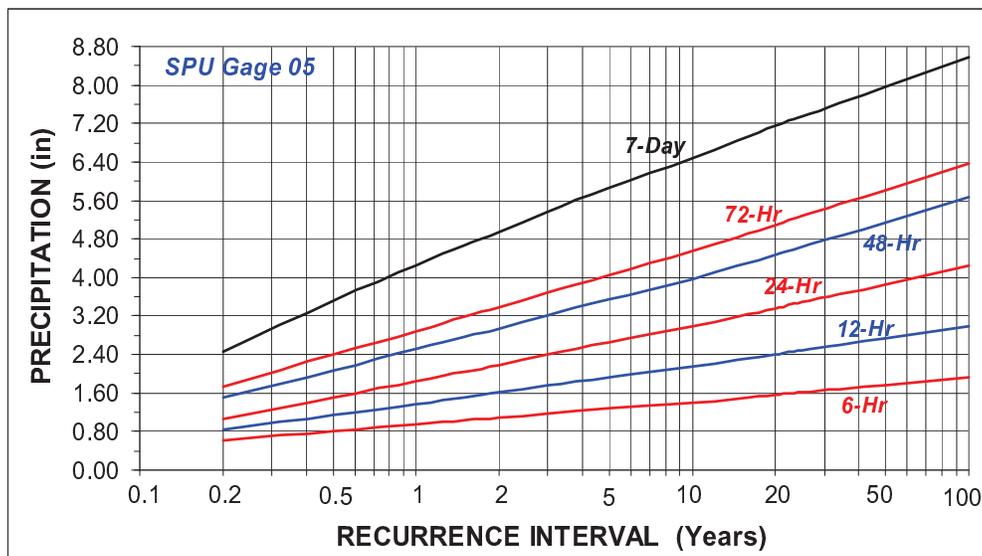
Duration (hr)	Precipitation (in)									
	Recurrence Interval (years)									
	0.2-Yr	0.5-Yr	1-Yr	2-Yr	5-Yr	10-Yr	20-Yr	25-Yr	50-Yr	100-Yr
6	0.58	0.75	0.88	1.02	1.20	1.33	1.48	1.52	1.67	1.82
12	0.76	1.05	1.26	1.47	1.76	1.96	2.19	2.27	2.49	2.72
24	0.93	1.32	1.61	1.91	2.31	2.61	2.94	3.04	3.37	3.71
48	1.34	1.85	2.22	2.62	3.15	3.54	3.99	4.13	4.58	5.04
72	1.53	2.11	2.53	2.97	3.56	3.98	4.47	4.62	5.10	5.58
168	2.11	3.01	3.63	4.24	5.02	5.55	6.12	6.29	6.83	7.34



**Figure E-5. Precipitation-Magnitude-Frequency Estimates for SPU Gage 04.**

**Table E-6. Precipitation-Magnitude-Frequency Estimates for SPU Gage 05.**

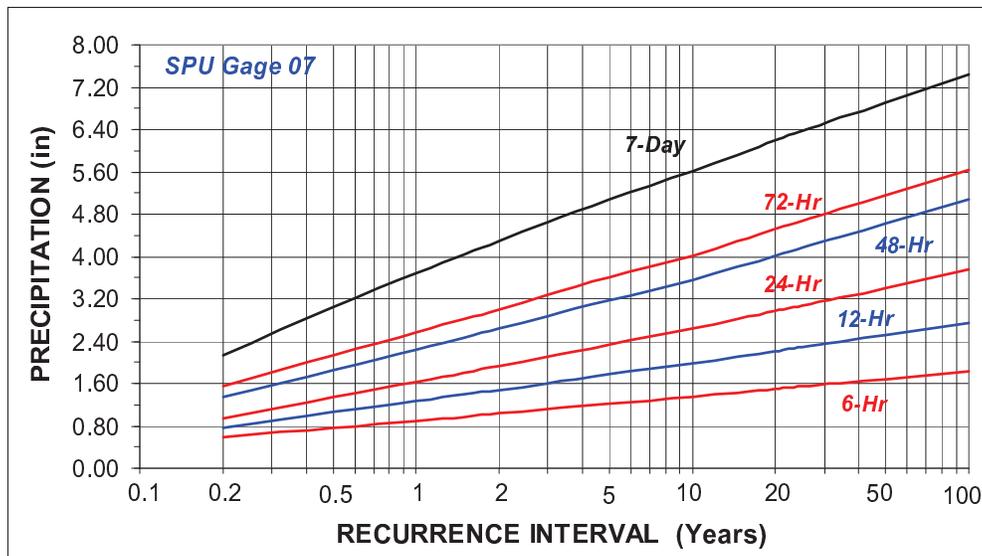
Duration (hr)	Precipitation (in)									
	Recurrence Interval (years)									
	0.2-Yr	0.5-Yr	1-Yr	2-Yr	5-Yr	10-Yr	20-Yr	25-Yr	50-Yr	100-Yr
6	0.61	0.80	0.94	1.08	1.27	1.41	1.57	1.62	1.77	1.93
12	0.84	1.15	1.38	1.61	1.93	2.15	2.40	2.49	2.74	2.99
24	1.06	1.51	1.84	2.19	2.65	2.98	3.36	3.48	3.86	4.24
48	1.51	2.08	2.50	2.94	3.54	3.98	4.48	4.64	5.15	5.67
72	1.74	2.40	2.89	3.39	4.06	4.55	5.09	5.27	5.82	6.37
168	2.47	3.52	4.24	4.96	5.86	6.48	7.14	7.35	7.97	8.57



**Figure E-6. Precipitation-Magnitude-Frequency Estimates for SPU Gage 05.**

**Table E-7. Precipitation-Magnitude-Frequency Estimates for SPU Gage 07.**

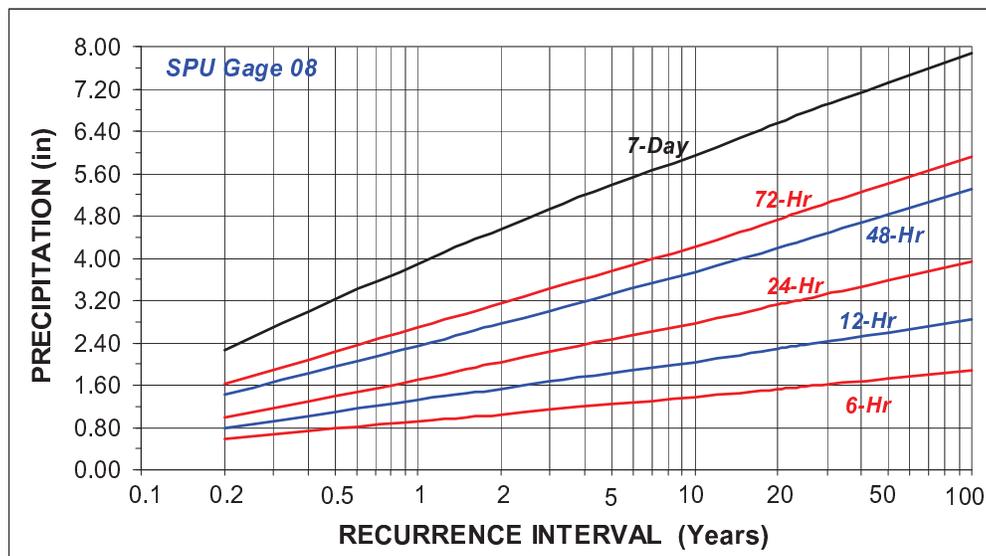
Duration (hr)	Precipitation (in)									
	Recurrence Interval (years)									
	0.2-Yr	0.5-Yr	1-Yr	2-Yr	5-Yr	10-Yr	20-Yr	25-Yr	50-Yr	100-Yr
6	0.58	0.76	0.89	1.03	1.21	1.34	1.49	1.54	1.69	1.84
12	0.77	1.06	1.27	1.48	1.77	1.97	2.21	2.28	2.51	2.74
24	0.94	1.33	1.63	1.93	2.34	2.63	2.97	3.07	3.41	3.75
48	1.35	1.86	2.24	2.64	3.18	3.57	4.02	4.16	4.62	5.08
72	1.54	2.13	2.56	3.00	3.60	4.03	4.51	4.67	5.15	5.64
168	2.14	3.05	3.68	4.30	5.08	5.61	6.19	6.37	6.91	7.43



**Figure E-7. Precipitation-Magnitude-Frequency Estimates for SPU Gage 07.**

**Table E-8. Precipitation-Magnitude-Frequency Estimates for SPU Gage 08.**

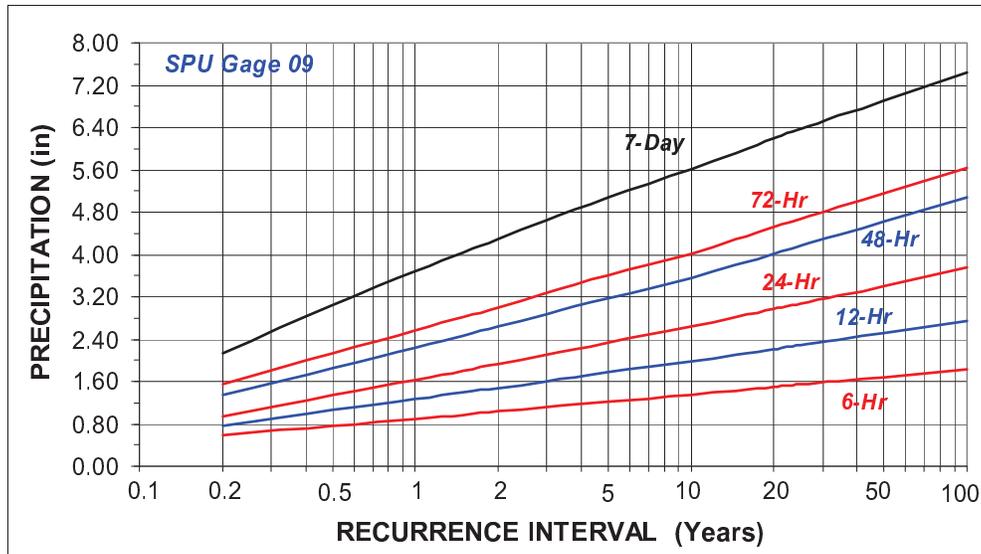
Duration (hr)	Precipitation (in)									
	Recurrence Interval (years)									
	0.2-Yr	0.5-Yr	1-Yr	2-Yr	5-Yr	10-Yr	20-Yr	25-Yr	50-Yr	100-Yr
6	0.59	0.78	0.91	1.05	1.24	1.37	1.52	1.57	1.72	1.87
12	0.80	1.09	1.31	1.53	1.83	2.04	2.28	2.36	2.60	2.84
24	0.98	1.41	1.71	2.03	2.46	2.77	3.12	3.24	3.59	3.94
48	1.41	1.95	2.35	2.76	3.32	3.73	4.20	4.35	4.83	5.32
72	1.62	2.23	2.68	3.14	3.77	4.22	4.73	4.89	5.40	5.91
168	2.27	3.23	3.90	4.55	5.39	5.95	6.56	6.75	7.33	7.88



**Figure E-8. Precipitation-Magnitude-Frequency Estimates for SPU Gage 08.**

**Table E-9. Precipitation-Magnitude-Frequency Estimates for SPU Gage 09.**

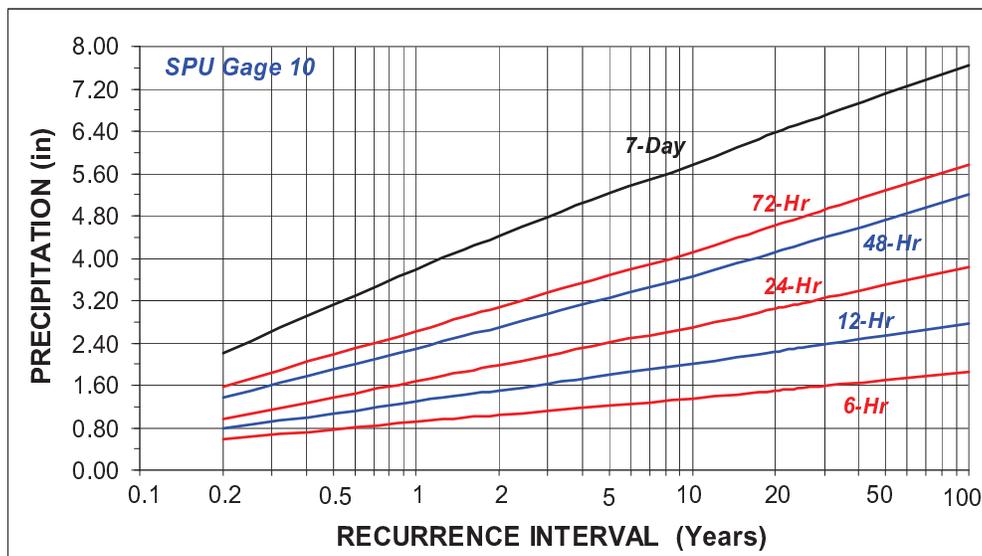
Duration (hr)	Precipitation (in)									
	Recurrence Interval (years)									
	0.2-Yr	0.5-Yr	1-Yr	2-Yr	5-Yr	10-Yr	20-Yr	25-Yr	50-Yr	100-Yr
6	0.58	0.76	0.89	1.03	1.21	1.34	1.49	1.54	1.69	1.84
12	0.77	1.06	1.27	1.48	1.77	1.97	2.21	2.28	2.51	2.74
24	0.94	1.33	1.63	1.93	2.34	2.63	2.97	3.07	3.41	3.75
48	1.35	1.86	2.24	2.64	3.18	3.57	4.02	4.16	4.62	5.08
72	1.54	2.13	2.56	3.00	3.60	4.03	4.51	4.67	5.15	5.64
168	2.14	3.05	3.68	4.30	5.08	5.61	6.19	6.37	6.91	7.43



**Figure E-9. Precipitation-Magnitude-Frequency Estimates for SPU Gage 09.**

**Table E-10. Precipitation-Magnitude-Frequency Estimates for SPU Gage 10.**

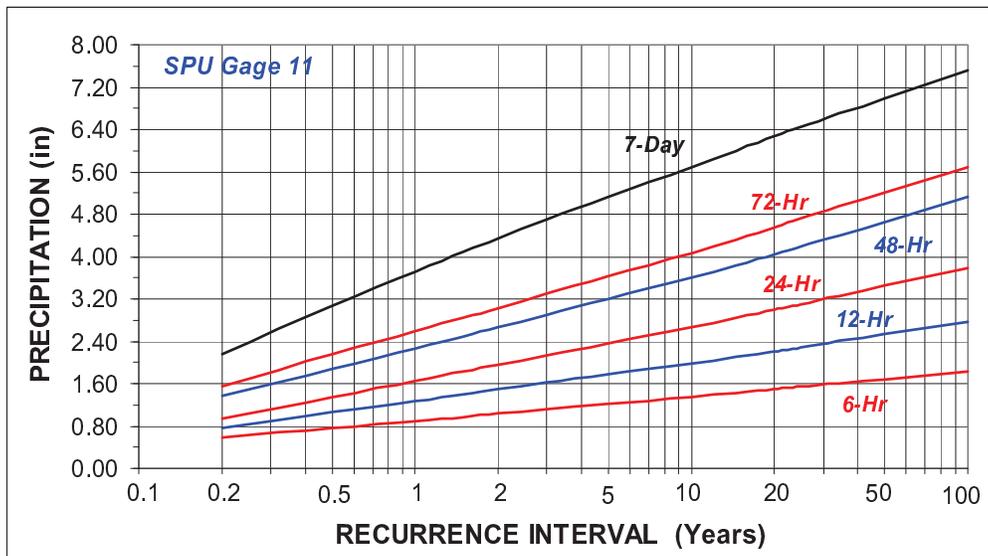
Duration (hr)	Precipitation (in)									
	Recurrence Interval (years)									
	0.2-Yr	0.5-Yr	1-Yr	2-Yr	5-Yr	10-Yr	20-Yr	25-Yr	50-Yr	100-Yr
6	0.59	0.77	0.90	1.04	1.22	1.36	1.51	1.55	1.70	1.86
12	0.78	1.07	1.28	1.50	1.79	2.00	2.24	2.31	2.55	2.78
24	0.96	1.37	1.67	1.98	2.40	2.70	3.05	3.16	3.50	3.85
48	1.38	1.91	2.29	2.70	3.25	3.65	4.11	4.26	4.72	5.20
72	1.58	2.18	2.62	3.07	3.68	4.12	4.62	4.78	5.27	5.78
168	2.20	3.14	3.78	4.42	5.23	5.78	6.37	6.55	7.11	7.64



**Figure E-10. Precipitation-Magnitude-Frequency Estimates for SPU Gage 10.**

**Table E-11. Precipitation-Magnitude-Frequency Estimates for SPU Gage 11.**

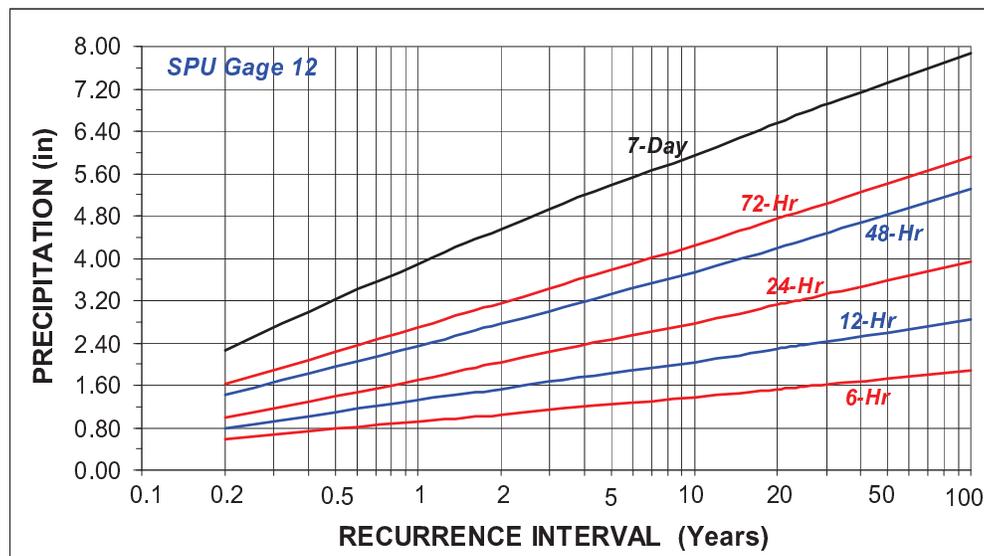
Duration (hr)	Precipitation (in)									
	Recurrence Interval (years)									
	0.2-Yr	0.5-Yr	1-Yr	2-Yr	5-Yr	10-Yr	20-Yr	25-Yr	50-Yr	100-Yr
6	0.58	0.76	0.89	1.03	1.21	1.34	1.49	1.54	1.69	1.84
12	0.77	1.06	1.27	1.49	1.78	1.99	2.22	2.30	2.53	2.76
24	0.95	1.35	1.64	1.95	2.36	2.66	3.00	3.11	3.44	3.79
48	1.36	1.88	2.26	2.66	3.20	3.60	4.05	4.19	4.65	5.12
72	1.56	2.15	2.58	3.03	3.63	4.07	4.56	4.71	5.20	5.70
168	2.16	3.08	3.72	4.35	5.14	5.68	6.27	6.45	6.99	7.52



**Figure E-11. Precipitation-Magnitude-Frequency Estimates for SPU Gage 11.**

**Table E-12. Precipitation-Magnitude-Frequency Estimates for SPU Gage 12.**

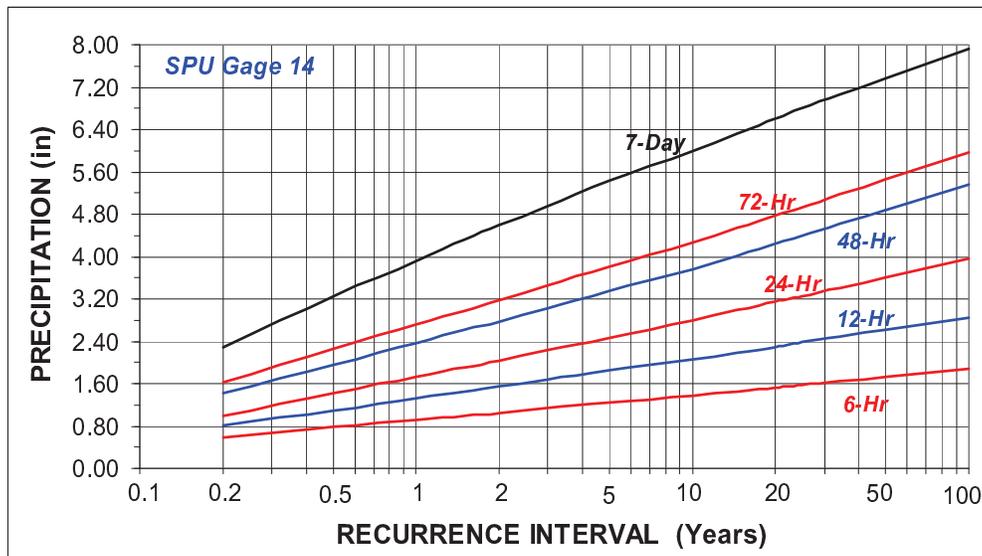
Duration (hr)	Precipitation (in)									
	Recurrence Interval (years)									
	0.2-Yr	0.5-Yr	1-Yr	2-Yr	5-Yr	10-Yr	20-Yr	25-Yr	50-Yr	100-Yr
6	0.59	0.78	0.91	1.05	1.24	1.37	1.52	1.57	1.72	1.87
12	0.80	1.09	1.31	1.53	1.83	2.04	2.28	2.36	2.60	2.84
24	0.98	1.41	1.71	2.03	2.46	2.77	3.12	3.24	3.59	3.94
48	1.41	1.95	2.35	2.76	3.32	3.73	4.20	4.35	4.83	5.32
72	1.62	2.24	2.69	3.16	3.78	4.23	4.74	4.90	5.41	5.93
168	2.27	3.23	3.90	4.55	5.39	5.95	6.56	6.75	7.33	7.88



**Figure E-12. Precipitation-Magnitude-Frequency Estimates for SPU Gage 12.**

**Table E-13. Precipitation-Magnitude-Frequency Estimates for SPU Gage 14.**

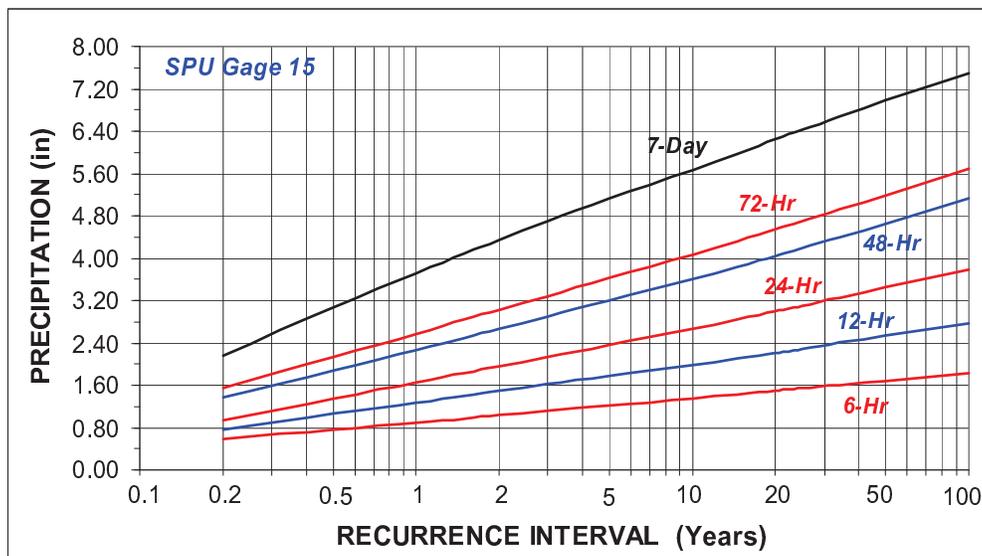
Duration (hr)	Precipitation (in)									
	Recurrence Interval (years)									
	0.2-Yr	0.5-Yr	1-Yr	2-Yr	5-Yr	10-Yr	20-Yr	25-Yr	50-Yr	100-Yr
6	0.59	0.78	0.91	1.05	1.24	1.37	1.52	1.57	1.72	1.87
12	0.80	1.10	1.32	1.54	1.84	2.06	2.30	2.38	2.61	2.86
24	0.99	1.41	1.72	2.04	2.48	2.79	3.14	3.25	3.61	3.96
48	1.42	1.96	2.36	2.78	3.35	3.76	4.23	4.39	4.87	5.36
72	1.63	2.25	2.71	3.18	3.81	4.26	4.77	4.94	5.45	5.97
168	2.28	3.25	3.92	4.58	5.42	5.99	6.61	6.80	7.38	7.93



**Figure E-13. Precipitation-Magnitude-Frequency Estimates for SPU Gage 14.**

**Table E-14. Precipitation-Magnitude-Frequency Estimates for SPU Gage 15.**

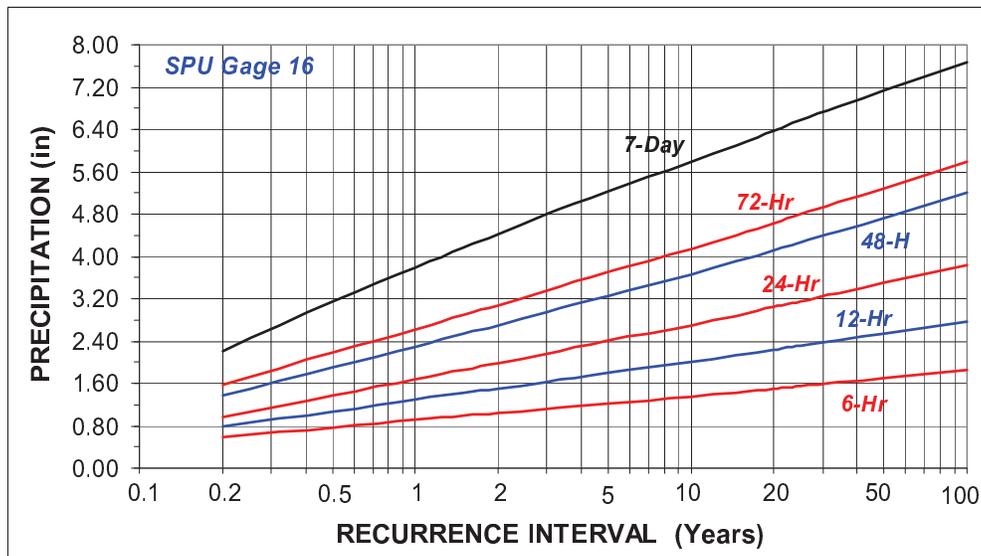
Duration (hr)	Precipitation (in)									
	Recurrence Interval (years)									
	0.2-Yr	0.5-Yr	1-Yr	2-Yr	5-Yr	10-Yr	20-Yr	25-Yr	50-Yr	100-Yr
6	0.58	0.76	0.89	1.03	1.21	1.34	1.49	1.54	1.69	1.84
12	0.77	1.06	1.27	1.49	1.78	1.99	2.22	2.30	2.53	2.76
24	0.95	1.35	1.64	1.95	2.36	2.66	3.00	3.11	3.44	3.79
48	1.36	1.88	2.26	2.66	3.20	3.60	4.05	4.19	4.65	5.12
72	1.55	2.14	2.58	3.02	3.62	4.05	4.54	4.70	5.19	5.68
168	2.16	3.08	3.71	4.34	5.13	5.67	6.25	6.43	6.98	7.50



**Figure E-14. Precipitation-Magnitude-Frequency Estimates for SPU Gage 15.**

**Table E-15. Precipitation-Magnitude-Frequency Estimates for SPU Gage 16.**

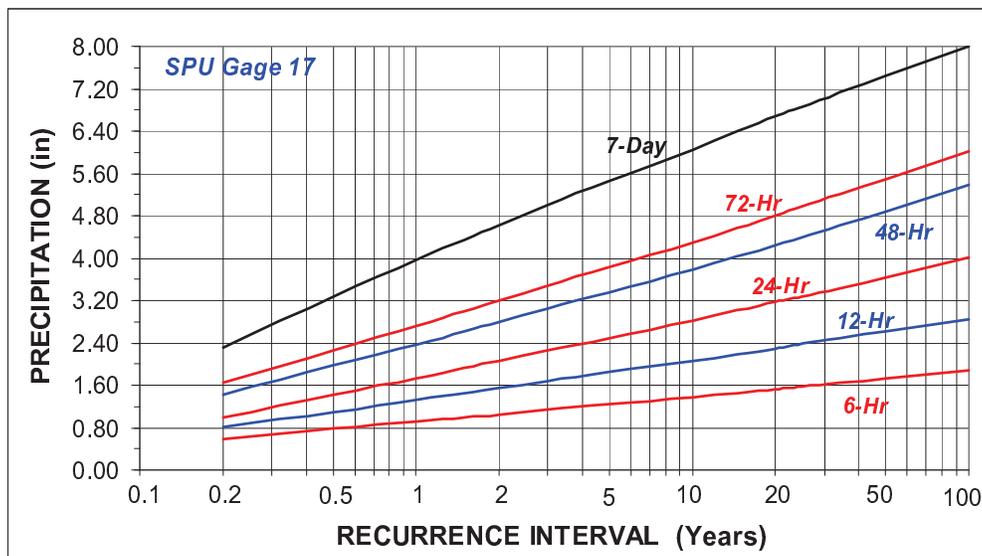
Duration (hr)	Precipitation (in)									
	Recurrence Interval (years)									
	0.2-Yr	0.5-Yr	1-Yr	2-Yr	5-Yr	10-Yr	20-Yr	25-Yr	50-Yr	100-Yr
6	0.59	0.77	0.90	1.04	1.22	1.36	1.51	1.55	1.70	1.86
12	0.78	1.07	1.28	1.50	1.79	2.00	2.24	2.31	2.55	2.78
24	0.96	1.37	1.67	1.98	2.40	2.70	3.05	3.16	3.50	3.85
48	1.38	1.91	2.29	2.70	3.25	3.65	4.11	4.26	4.72	5.20
72	1.58	2.19	2.63	3.08	3.70	4.13	4.63	4.79	5.29	5.80
168	2.20	3.14	3.79	4.43	5.24	5.79	6.39	6.57	7.13	7.66



**Figure E-15. Precipitation-Magnitude-Frequency Estimates for SPU Gage 16.**

**Table E-16. Precipitation-Magnitude-Frequency Estimates for SPU Gage 17.**

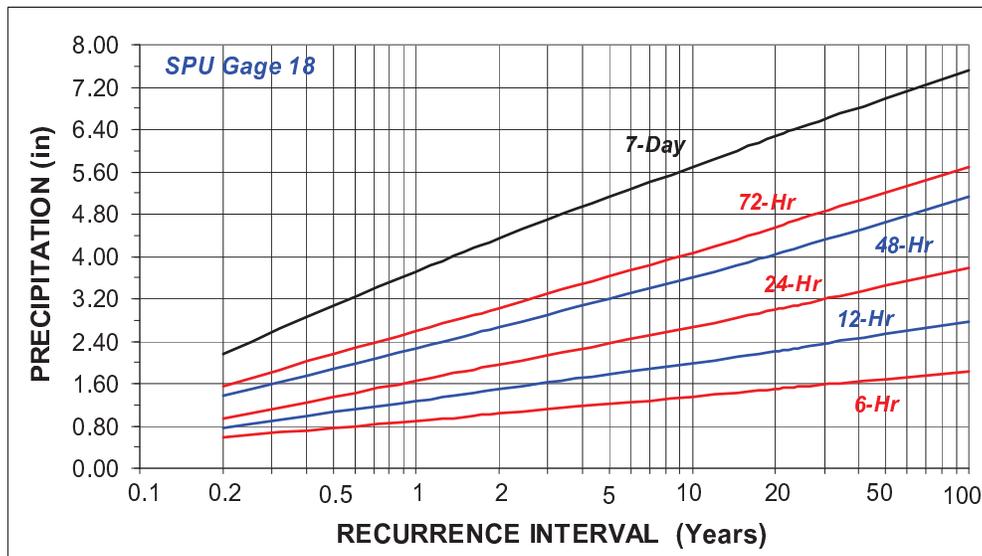
Duration (hr)	Precipitation (in)									
	Recurrence Interval (years)									
	0.2-Yr	0.5-Yr	1-Yr	2-Yr	5-Yr	10-Yr	20-Yr	25-Yr	50-Yr	100-Yr
6	0.59	0.78	0.91	1.05	1.24	1.37	1.52	1.57	1.72	1.87
12	0.80	1.10	1.32	1.54	1.84	2.06	2.30	2.38	2.61	2.86
24	1.00	1.43	1.74	2.06	2.50	2.81	3.17	3.29	3.64	4.00
48	1.43	1.97	2.37	2.79	3.36	3.77	4.25	4.40	4.88	5.37
72	1.64	2.27	2.72	3.20	3.83	4.29	4.80	4.97	5.49	6.01
168	2.30	3.28	3.96	4.63	5.47	6.05	6.67	6.86	7.44	8.00



**Figure E-16. Precipitation-Magnitude-Frequency Estimates for SPU Gage 17.**

**Table E-17. Precipitation-Magnitude-Frequency Estimates for SPU Gage 18.**

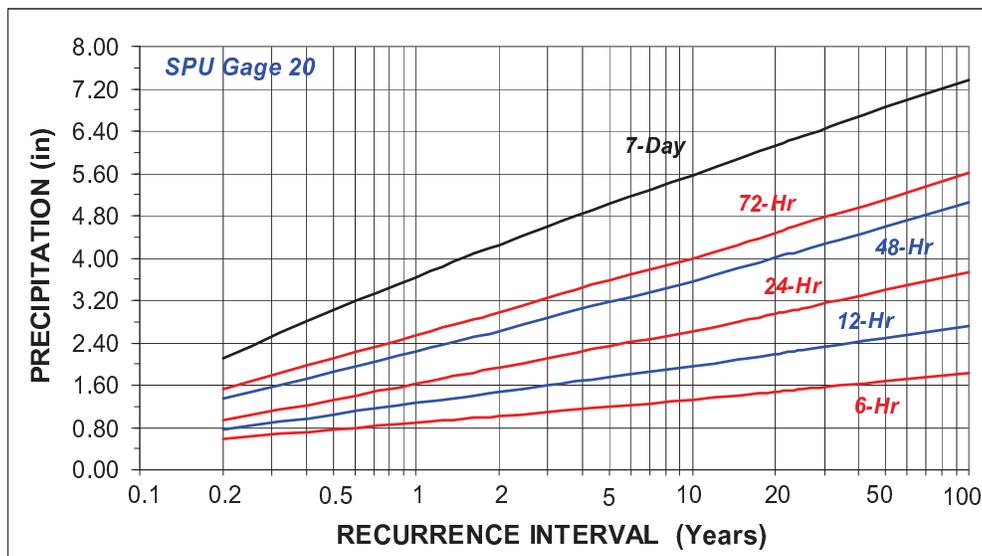
Duration (hr)	Precipitation (in)									
	Recurrence Interval (years)									
	0.2-Yr	0.5-Yr	1-Yr	2-Yr	5-Yr	10-Yr	20-Yr	25-Yr	50-Yr	100-Yr
6	0.58	0.76	0.89	1.03	1.21	1.34	1.49	1.54	1.69	1.84
12	0.77	1.06	1.27	1.49	1.78	1.99	2.22	2.30	2.53	2.76
24	0.95	1.35	1.64	1.95	2.36	2.66	3.00	3.11	3.44	3.79
48	1.36	1.88	2.26	2.66	3.20	3.60	4.05	4.19	4.65	5.12
72	1.56	2.15	2.58	3.03	3.63	4.07	4.56	4.71	5.20	5.70
168	2.16	3.08	3.72	4.35	5.14	5.68	6.27	6.45	6.99	7.52



**Figure E-17. Precipitation-Magnitude-Frequency Estimates for SPU Gage 18.**

**Table E-18. Precipitation-Magnitude-Frequency Estimates for SPU Gage 20.**

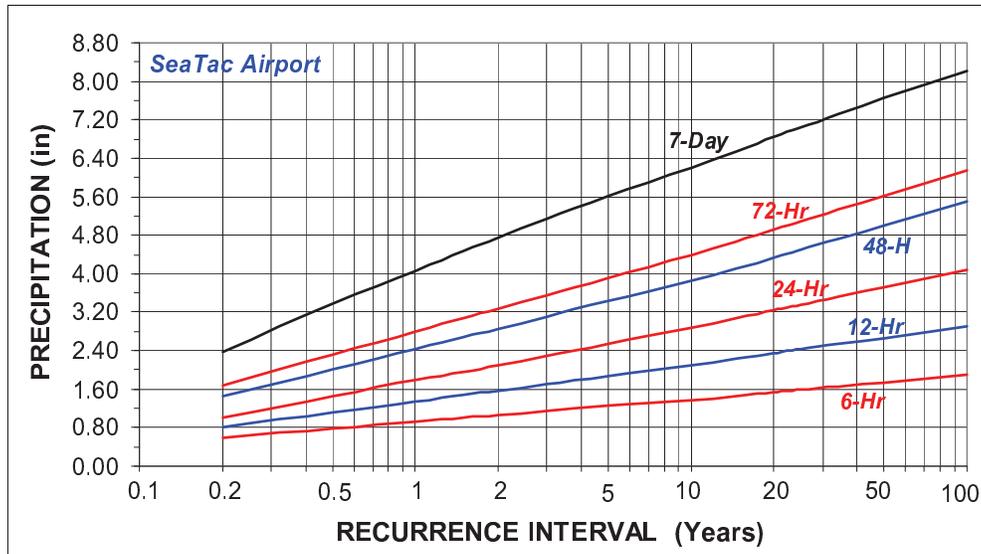
Duration (hr)	Precipitation (in)									
	Recurrence Interval (years)									
	0.2-Yr	0.5-Yr	1-Yr	2-Yr	5-Yr	10-Yr	20-Yr	25-Yr	50-Yr	100-Yr
6	0.58	0.75	0.88	1.02	1.20	1.33	1.48	1.52	1.67	1.82
12	0.76	1.05	1.26	1.47	1.76	1.96	2.19	2.27	2.49	2.72
24	0.93	1.33	1.62	1.92	2.33	2.62	2.95	3.06	3.39	3.73
48	1.35	1.86	2.23	2.63	3.16	3.55	4.00	4.15	4.60	5.06
72	1.53	2.11	2.54	2.98	3.57	4.00	4.48	4.64	5.12	5.60
168	2.12	3.02	3.64	4.25	5.03	5.56	6.13	6.31	6.84	7.36



**Figure E-18. Precipitation-Magnitude-Frequency Estimates for SPU Gage 20.**

**Table E-19. Precipitation-Magnitude-Frequency Estimates for SeaTac.**

Duration (hr)	Precipitation (in)									
	Recurrence Interval (years)									
	0.2-Yr	0.5-Yr	1-Yr	2-Yr	5-Yr	10-Yr	20-Yr	25-Yr	50-Yr	100-Yr
6	0.60	0.78	0.92	1.06	1.25	1.38	1.54	1.58	1.74	1.89
12	0.82	1.12	1.34	1.57	1.88	2.10	2.34	2.42	2.67	2.91
24	1.02	1.45	1.77	2.11	2.55	2.87	3.23	3.35	3.72	4.08
48	1.46	2.01	2.42	2.85	3.43	3.86	4.34	4.50	4.99	5.49
72	1.68	2.32	2.78	3.27	3.92	4.38	4.91	5.08	5.61	6.14
168	2.36	3.37	4.06	4.75	5.62	6.21	6.85	7.04	7.64	8.22



**Figure E-19. Precipitation-Magnitude-Frequency Estimates for SeaTac.**

# **APPENDIX D. RECOMMENDATIONS FOR FUTURE CONVEYANCE PLANS**

This section describes some of the challenges faced when trying to use existing sources of data. In general, this data was in multiple locations and it often was not in a format that allowed it to be easily utilized during basin planning efforts.

## D.1 IMPROVEMENTS TO GIS DATA

Model development is dependent on the data (e.g., rims elevations, invert elevations, pipe network configurations) being correct within the GIS system. Missing information is interpolated or, if deemed necessary, assessed by field crews. The accuracy of the existing information is critical to being able to accurately model the system.

By reducing the amount of missing information and improving the accuracy, the model creation process will be greatly sped up and the accuracy of the models will be improved. If the basin-wide models are planned to be used to evaluate conditions at specific areas upstream from the outfall (e.g., not evaluating the basin as a whole), this effort is critical.

### Recommended Changes

1. Fill in data gaps (i.e., missing rims, missing inverts, missing sumps) in the GIS system. Request submitted to Technical Services group to gather missing data through field verification. Initial focus area for the work is FS-05 and FS-06 followed by areas of the system with significant amounts of missing data with close proximity to each other. Missing sanitary information in the same vicinity will be collected at the same time since this information will be needed to support future sanitary modeling efforts.
2. Periodic evaluation of GIS data is needed to fix obvious errors. This work should include comparisons of rim elevations to lidar, looking for inverts that are below sumps of connected manholes, and finding negatively sloped pipes. A request has been submitted for a comparison of rims versus lidar information, but the other items have not been submitted. Input is needed from the GIS technicians on the best ways to check the accuracy of the GIS data. The goal is not to get 100% accuracy, but to identify and fix obvious errors in the data sets.
3. Field survey information should be input back into the GIS system, especially when field surveys occur in areas that are not going to be changed as part of a future capital project. A process needs to be developed between the survey crews, engineers, and technicians to streamline this process. Currently, updates are only made if engineers submit a GIS update request.
4. Flow splitters (e.g., manholes with a weir wall) are not easily found within the GIS system. Flow splitters should either be given a separate asset tag or the associated manholes should be tagged in a way (e.g., 61XXXXX vs 60XXXXX) that allows them to be easily identified in GIS. For this conveyance plan, efforts were not made to try to identify these flow splitter devices since the effect at the basin scale is minimal. When models of smaller areas are requested, however, this flow splitter information will be important to understanding the local system.
5. The I&I crew has smoke tested a significant portion of the City and this information is currently available by address. For modeling purposes, downspouts and catch basins that were connected to sanitary were turned into GIS layers so the scope of the cross

connections could be better understood. While this information was not included in this model<sup>26</sup> since the impacts at the basin scale are negligible, this information will be important to incorporate into modeling of smaller areas. In order to make the smoke testing data more usable for modeling purposes, it is recommended to keep these GIS layers updated (or change the way the data is collected) as additional smoke testing occurs. This GIS based smoke testing data will also be useful for future modeling of the sanitary system.

6. Other types of stormwater facilities that may affect flow through the system (e.g., infiltration facilities, detention ponds) are not easily found in the GIS system. These need to be clearly identified so that they can be added to the model.

## D.2 CONDITION ASSESSMENTS

Condition assessments of the pipes are critical to making decisions about the remaining life of the asset and associated risk of failure. To improve the value of the existing data for basin planning purposes, the following improvements/changes are recommended.

### Recommended Changes

1. “Red” currently identifies pipe that requires an open cut. This could either mean that a spot repair(s) is required or that the entire pipe segment needs to be replaced. Identifying in the assessment database (either through a separate field or a new color) whether a spot repair or a main replacement is required would improve basin planning. Mike Rose is currently working on implementing this fix.
2. Pipes are currently identified as “red” if there is a capacity issue identified either through known field conditions or from modeling done as part of permit submittals to the Site Development Group. These pipes may or may not have had a condition assessment. In order to evaluate the condition and capacity information separately and develop prioritized project lists, the capacity information should be tracked separately from the condition information. The GovMe layer is currently setup for this, but corrections to the condition assessments are needed to remove capacity information. (Note: Capacity information was added to the condition layer to speed up the plan review process so that reviewers only had to look on one layer for the information. If viewing only one layer is important to the plan review group, this can still be achieved with some programming work (i.e., create a combined layer showing the worst assessment between the capacity and condition fields.)
3. Several pipes have videos available for review in Granite, but there is no assessment in the STRAP database. It would be beneficial to perform the engineer review of the videos in Granite and add this information to the STRAP database. A process should also be developed for the engineers who request Granite inspections to record their review and input this into the STRAP database. Alternatively, a relationship between the

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<sup>26</sup> A previous model of FS-05 did take catch basin and roof cross-connections into account. The results at the basin scale were negligible (1% change in peak flows), so this analysis was not performed on this combined FS-05/FS-06 model.

- PACP score generated as part of the pipe inspection and the STRAP red/yellow/green rating can be developed so pipes can automatically be assigned a rating in STRAP.
4. Pipes that were attempted to be assessed via STRAP, but could not be (due to access issues, etc.) are shown as both yellow and green in the STRAP database along with a comment stating that the pipe assessment could not be performed. Since these comments are not easily viewable on a basin wide scale, these pipes should be tracked differently (either through a separate field or a new color). Mike Rose is currently working on implementing this fix.
  5. Several videos were observed in the Granite system where the inspection was performed while the pipe was submerged during high tide. These inspections are not usable and another inspection needs to be performed. Inspection crews should be directed to coordinate inspections of tidally influenced pipes to low tide periods.
  6. Assessments were not available for some of the stormwater trunk lines (e.g., downstream from 21<sup>st</sup> and Pacific) in FS-05 and FS-06. Pipe assessments should be prioritized to assess the pipes with the largest consequence of failure (e.g., main trunk lines due to the volume of water they carry, pipes on steel hill sides) first. Alternate inspection methodology (e.g., not via crawler cameras or STRAP) may be required to assess some of these pipes.

### **D.3 KNOWN CAPACITY ISSUE DATA**

Several sources of data are available for review to identify flooding locations including the EOC database, source control spills and complaints database, source control claims database, legal department claims database, and personal communications with engineering and transmission<sup>27</sup>. Other than the EOC database, all of this data has challenges with associating the information with specific addresses.

#### **Recommended Changes**

1. Modify the source control claims and the spills and complaints databases to either require a parcel number be selected or the standardized GovMe address format be used. The current free form address entries make querying and mapping the data very challenging.
2. Fields that track key information (e.g., stormwater system vs. sanitary system) should be required from the user and fields that default to “other” should require user input prior to creating the new entry. This will make mapping and querying of data easier.
3. The claims information maintained by the Legal Department does not include addresses. The source control claims database could either be amended to track the amount paid for each claim or a claim number field added to the database so that it can be linked to the Legal Department’s claim database.
4. Fields in the source control spills and complaints database and the EOC database should be updated to better identify the cause of the flooding event (e.g., surcharged storm system, private property drainage issue, leaves on catch basin) should be added

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<sup>27</sup> These are the sources of information that were known at the time that this Plan was developed. Additional research is needed to determine if this information is tracked in other locations.

to the database. The cause of the flooding is currently documented in the notes fields, but it is challenging query these notes fields. The fields that are needed should be developed with input from transmission and engineering to ensure that the gathered information is useful to the end users.

#### **D.4 EVALUATION OF TACOMA HISTORIC RAINFALL**

Conveyance sizing is very sensitive to the rainfall events used in the model. The 100-year, Type IA, 24-hour event represents long, large storms, but does not accurately depict the short duration, high peak intensity events.

Instead of modeling the 100-year, Type IA, 24-hour event, Seattle Public Utilities requires modeling of short (2-hour), intermediate (6-hour), and long (24-hour) rain events in their stormwater manual. Instead of using the Type IA rainfall distribution, Seattle created their own design storm distributions based on “noteworthy storms that were recorded by the City of Seattle gauging network” (Appendix B). In addition, Seattle evaluated their historic rainfall data and generated their own Intensity-Duration-Frequency (IDF) curves and Precipitation-Magnitude-Frequency charts (Appendix C). This information is used instead of the 24-hour rainfall isopleths available from NOAA. Please note that a 100-year, 2-hour event under Seattle’s design methodology has a peak of 0.22/5 minutes. In comparison, the 100-year, Type IA, 24-hour event has a peak of 0.10 in/6 minute or a 0.16 in/10 minutes<sup>28</sup>.

##### **Recommended Changes**

1. Evaluate Tacoma’s historic rainfall and generate Intensity-Duration-Frequency (IDF) curves and Precipitation-Magnitude-Frequency charts based on this data. Once these charts are available, evaluate the Type IA, 24-hour modeling approach and update, as appropriate.

#### **D.5 PROGRAMMATIC RANKING OF CAPITAL IMPROVEMENT PROJECTS**

While this Plan identifies capital improvement projects in the FS-05 and FS-06 basin for the new trunk main, it does not provide information about how these projects rank in comparison to other capital improvement projects with the City. In addition to ranking the projects within the storm sewer system, the rankings of other City assets (e.g., sanitary, roads, water lines) should be evaluated concurrently to determine how City resources could be best spent. This ranking process should incorporate the pipe condition information and the water quality information included in this Plan.

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<sup>28</sup> For modeling purposes, the City has been using a peak of 0.22 in/10 minutes as its standard 100-year, Type IA, 24-hour event.