Louis Berger

# Expanded Plan for Conveyance Improvements in North Shellebarger Subbasin

City of Edmonds, Washington
Department of Public Works

June 2015

louisberger.com

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# Expanded Plan for Conveyance Improvements in North Shellabarger Subbasin

## City of Edmonds

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# Section 1
# Introduction

In 2013 and early 2014, Louis Berger assisted the City of Edmonds on the North Shellabarger Subbasin Plan for Conveyance Improvements. The objective of the study was to evaluate specific known flooding problems along the primary drainage system and develop recommended solutions that would alleviate the flood hazards. The study included hydrologic and hydraulic modeling of the primary drainage system within the subbasin.

In late 2014, the City of Edmonds retained Louis Berger to build upon the prior work and complete this expanded Subbasin Plan. Whereas the purpose of the prior investigation was focused on specific known flooding problem areas, this expanded study has the goal to evaluate the entire drainage system within the subbasin and identify additional undersized pipe based upon hydrologic and hydraulic modeling. This effort is needed to provide information on undersized drainage system pipes that can feed into an expanded City removal and replacement program for the area. The City's expanded removal and replacement program includes storm drains, sewer pipe, and water pipe and the City is conducting separate condition assessments of these systems. The information on which storm drains are undersized and to the degree they are undersized can provide useful information to the City in setting project priorities.

To be cost effective in this updated expanded basin plan, yet include all of the information develop for the subbasin in one report, the report is organized into 3 report sections. Section 1 is an introduction. Section 2 includes North Shellabarger Subbasin Plan for Conveyance Improvements, as described in the prior study effort, except that any updates to the modeling results from this work are incorporated into the Section 2 updates. Section 3 describes with work of this Expanded Subbasin Plan. The goals of the Expanded Subbasin Plan include:

- Complete hydrologic/hydraulic modeling of the subbasin drainage system and identify existing conveyance level of protection provided by the systems.
- For those system that are undersized, identify a replacement size to increase the level of protection provided by the system.
- Develop cost estimates (generally in block by block segments) for any recommended pipe replacements.
- Provide this data such that the City can use the information in helping prioritize system replacements.

# Section 2
# North Shellabarger Subbasin – Primary Drainage System Evaluation

This Section includes a summary of the work that was completed to evaluate and recommend improvements to reduce the risk of flood hazards at previously known flooding areas in the North Shellabarger subbasin in Edmonds. The North Shellabarger subbasin generally extends from 3rd Ave S to 9th Ave S, between Cedar St and Main St. In the effort to develop the plan, the study included hydrologic and hydraulic modeling to identify the level of flood protection provided by the existing primary drainage system.

## 2.1 Background

There are three known recurrent flooding problems in the North Shellabarger subbasin. In addition, major flooding occurred at two additional areas on August 29th, 2013 along 5th Ave S between Dayton St and Maple St. The North Shellabarger subbasin is presented on Figure 2-1. This figure also shows the City-identified problem areas as well as the conveyance system within the subbasin. The City-identified problems include the following:

- Flooding Area 1 – recurrent flooding of the alley between 3rd Ave S and 4th Ave S and Dayton St and Walnut St. Past City observations indicate that the low area along 4th Ave S south of Dayton St ponds and overflows west towards this alley and contributes to the recurrent problem.
- Flooding Area 2 – recurrent flooding of the low point along 4th Ave S between Dayton St and Walnut St.
- Flooding Area 3 – flooding at the intersection of 5th Ave S and Maple St. This was observed during the August 29th, 2013 flood.
- Flooding Area 4 - flooding at the intersection of 5th Ave S and Dayton St. This was observed during the August 29th, 2013 flood.
- Flooding Area 5 – recurrent flooding along Dayton St just west of 7th Ave S. This flooding may be in part due to root intrusion. The City has already identified a project to replace this pipe as part of the City's Comprehensive Surface Water Plan.

The recurrent and more recent flooding problems prompted the City to retain Louis Berger to conduct a subbasin study with the following objectives;

- Identify the level of flood protection provided by the subbasin's primary drainage system,
- Recommend improvements to increase the level of flood protection, and recommend an early action project to address two of the recurrent flooding problems at Flooding Areas 1 and 2.

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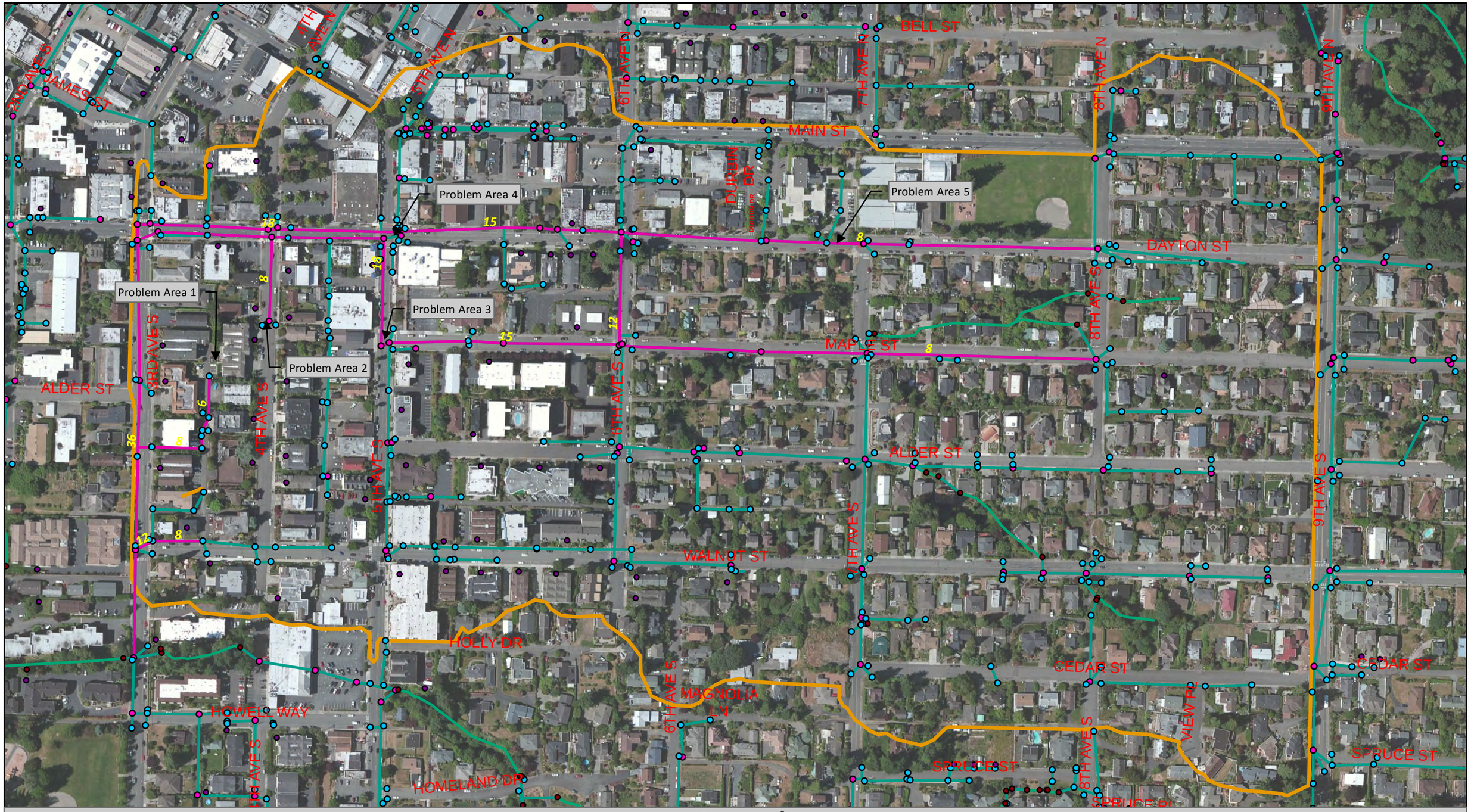


## Legend

N

1 inch = 250 feet

0 125 250 500 Feet

- Storm Catch Basin Type 1
- Storm Catch Basin Type 2
- Modeled Primary Drainge System
- Storm Pipe or Channel
- Basin Boundary

Figure 2-1
North Shellabarger Subbasin

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Several photographs of flooding during the August 29th, 2013 rain event are shown on Figure 2-2. These photographs were downloaded from the photo sharing website (http://natfoot.smugmug.com) following the flood event. The photographs suggest that the system along 5th Ave S lacked capacity during this major flood as evidenced in Photo 5 taken at Maple Street where stormwater is "geysering" from a catch basin in the intersection (Photo 5). The ponded water in the intersection (Flooding Area 3) is also observed in Photos 6 and 7. This ponded water flows north towards Dayton St along the curb as shown in Photo 4. Photos 1, 2 and 3 show ponding at the intersection of 5th Ave S and Dayton St (Flooding Area 4).

## 2.2 Field Survey for Early Action Conveyance Improvements

In support of the effort to identify early action design improvements to address Flooding Areas 1 and 2, the City contracted with DHA Surveyors to develop a survey and basemap of the drainage system in this area. This area included both the alley between 3rd Ave S and 4th Ave S and 4th Ave S south of Dayton Street. Information developed from this survey was used in the hydrologic modeling analysis.

In addition, two pipe systems that drain the flooding areas were "TV-d" to assess their condition (on Figure 2-4, these pipe segments are between structures 7-370 to structure 7-38 (for the 4th Ave S system) and structure 7-228 to the connection to the 36-inch diameter pipe on the west side of 3rd Ave S to the west of structure 7-229 (for the alley system)[1]. Summary results from the TV-ing were as follows (see Attachment D for more information):

- 4th Ave S. The 4th Ave S system is generally in poor condition with differential settlement creating high points and low points. The concrete at the bottom of the pipe is worn, increasing pipe roughness.
- Alley system. Most of the pipe segment was in moderate condition with some root intrusion. However, there was a point in the system downstream of structure 7-229 (see Figure 2-4) where the pipe was separated at a joint and the camera could not pass. This section of pipe was subsequently exposed by City maintenance staff and it was determined that the joint had separated and the pipe size had been reduced to 6-inches in diameter, whereas the rest of the pipe was 8-inch diameter pipe. City crews replaced the partially blocked section of pipe with 8-inch diameter pipe so that it is now functioning properly. For the hydraulic modeling of this system, the 8-inch pipe size was used.

[1] CBs 16 and 17 in Appendix D are structures 7-370 and 7-38, respectively on Figure 2-4. CB-W and CB-E in Appendix D are curb inlets that connect to structure 7-370 on Figure 4. CB6 in Appendix D is structure 7-228 in Figure 2-4.

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| Photo(s) | Location | Description |
|---|---|---|
| 1,2,3 | Intersection of Dayton St and 5th Ave | Flooding along 5th Ave, Looking South Towards Maple St |
| 4 | Intersection of Maple St and 5th Ave | Flooding along 5th Ave, Looking North Towards Dayton St |
| 5 | Intersection of Maple St and 5th Ave | Flooding at Intresection (Stormwater Ejecting from Manhole) |
| 6,7 | Intersection of Maple St and 5th Ave | Flooding at Intersection, Looking North |
| 8 | Intersection of Dayton St and 3rd Ave | Flooding at Intersection, Looking North |


N

1 inch = 125 feet

Feet

0 50 100 200

## Legend

- Storm Catch Basin Type 1
- Storm Catch Basin Type 2
- Storm Pipe or Channel

**Note:**

These photos shows the flooding that occured at flooding areas 3 and 4 during the August 29th, 2013 storm event. No photos were found for flooding areas 1, 2 and 5.

Figure 2-2
Flooding Photos

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## 2.3 Hydrologic and Hydraulic Analysis

An XPSWMM model was developed to simulate both the hydrology of the subbasin and hydraulics of the primary conveyance system. The primary conveyance system generally includes the moderate to large piped conveyance system (highlighted in color on Figure 1). Data for the XPSWMM model was mostly obtained from the City's GIS maps, except in areas where survey data was available from the proposed early action conveyance improvements for Flooding Areas 1 and 2.

The outfall to Shellabarger Creek was used as the downstream boundary condition. The outfall was chosen because it drains to a relatively steep portion of the creek and as such normal flow can be used for the boundary condition. The upstream subbasin boundary was then defined based upon available LiDAR topographic mapping and City GIS drainage system mapping. The subbasin was divided into 16 subbasins at different inflow points into the primary drainage system. The subbasin delineation was then modified at a couple locations based on a site visit on November 8th, 2013. The delineated subbasins and existing drainage system are shown on Figure 2-3.

During the site visit, one observation was a general lack of drainage inlets, particularly on the steeper portions of the basin east of 6th Ave S and north of Alder St. The lack of inlets could result in gutter flows exceeding the capacity of inlets and overflowing downslope to overwhelm some downstream drainage inlet.

The drainage system modeled in XPSWMM is shown on Figure 2-4. This figure also presents the XPSWMM model nodes (typically catch basins). The modeled system consists of the main storm lines on 3rd Ave S, Dayton St and Maple St with the connector pipes on 6th Ave S and 5th Ave S. The smaller systems on 4th Ave S, the alley between 3rd Ave S and 4th Ave S, and a short pipe segment on Walnut St associated with Flooding Areas 1 and 2 were also included so that the effect of possible early action conveyance improvements could be accounted for in the modeling. The drainage system on Dayton St west (downstream) of 5th Ave S consists of two parallel 18-inch diameter concrete pipes that connect to a 36-inch diameter concrete trunk on 3rd Ave S. This trunk extends south to the Shellabarger Creek outfall. Pipe sizes increase from 8-inch diameter at 8th Ave S in the upstream end of the subbasin to 36-inch diameter pipe along 3rd Ave S. The general slope of the subbasin is to the west with the portion of the subbasin east of 5th Ave S being steeper than the rest of the subbasin.

At the intersection of 6th Ave S and Maple St, the pipe system allows flows to be split in two directions. One pipe system on 6th Ave S conveys flow north to the intersection to a catch basin and then west along Maple St. A second pipe system on Maple St conveys flow west toward the intersection where it connects to a catch basin that has two outlets. One extends north along 6th Ave S, while the other connects to the system that conveys flow west along Maple St. A sketch of the intersection piping is included in Attachment C.

The City's GIS drainage maps show that drainage at the intersection of 7th Ave S and Alder St could also flow in two directions. However, more detailed review of the GIS showed that the system extending west from the intersection was intentionally plugged so that all flow extends north along 7th Ave S.

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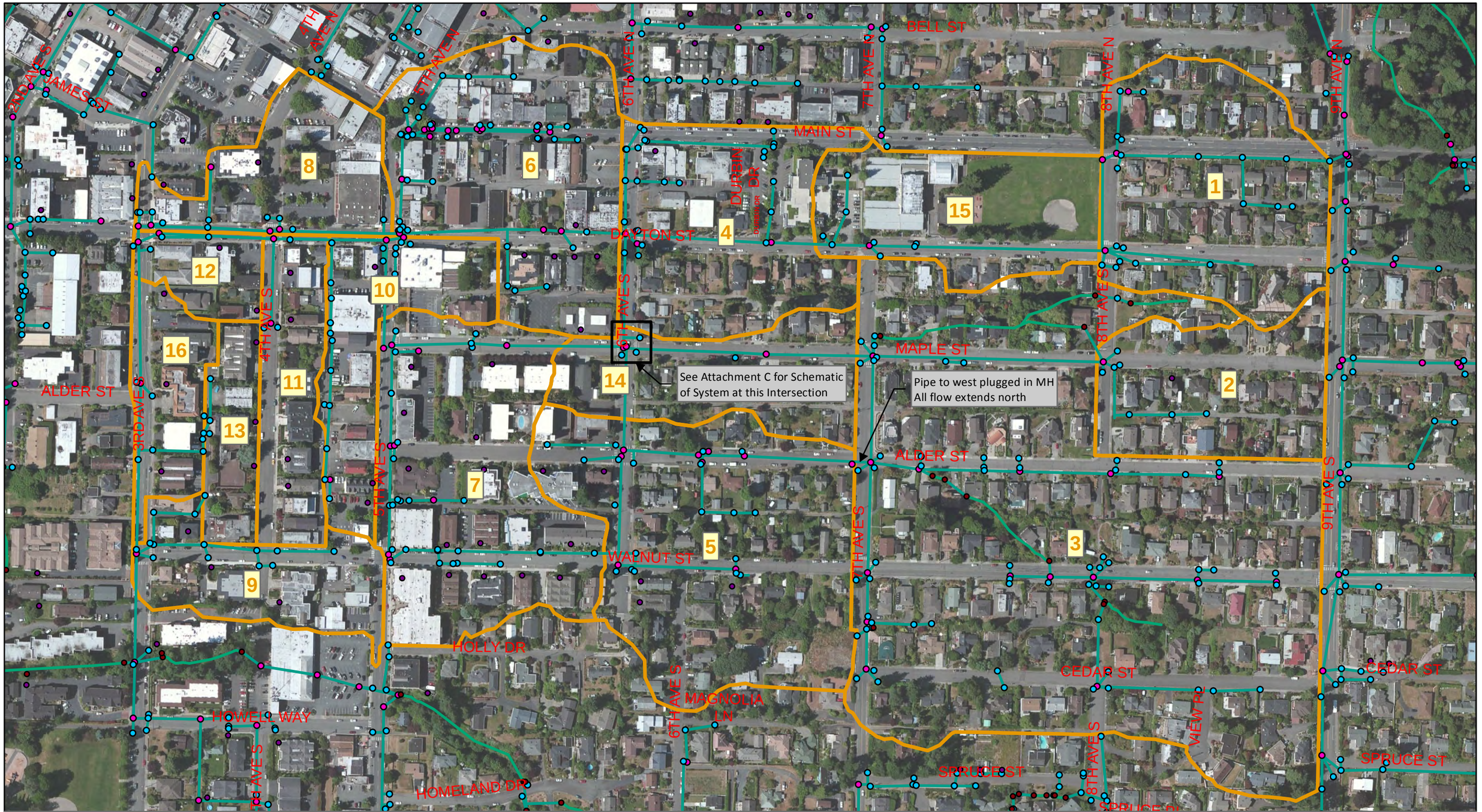


N

1 inch = 250 feet

0 125 250 500 Feet

## Legend

- Storm Catch Basin Type 1
- Storm Catch Basin Type 2
- Storm Pipe or Channel
- Subbasins

Figure 2-3
Subbasin Boundaries

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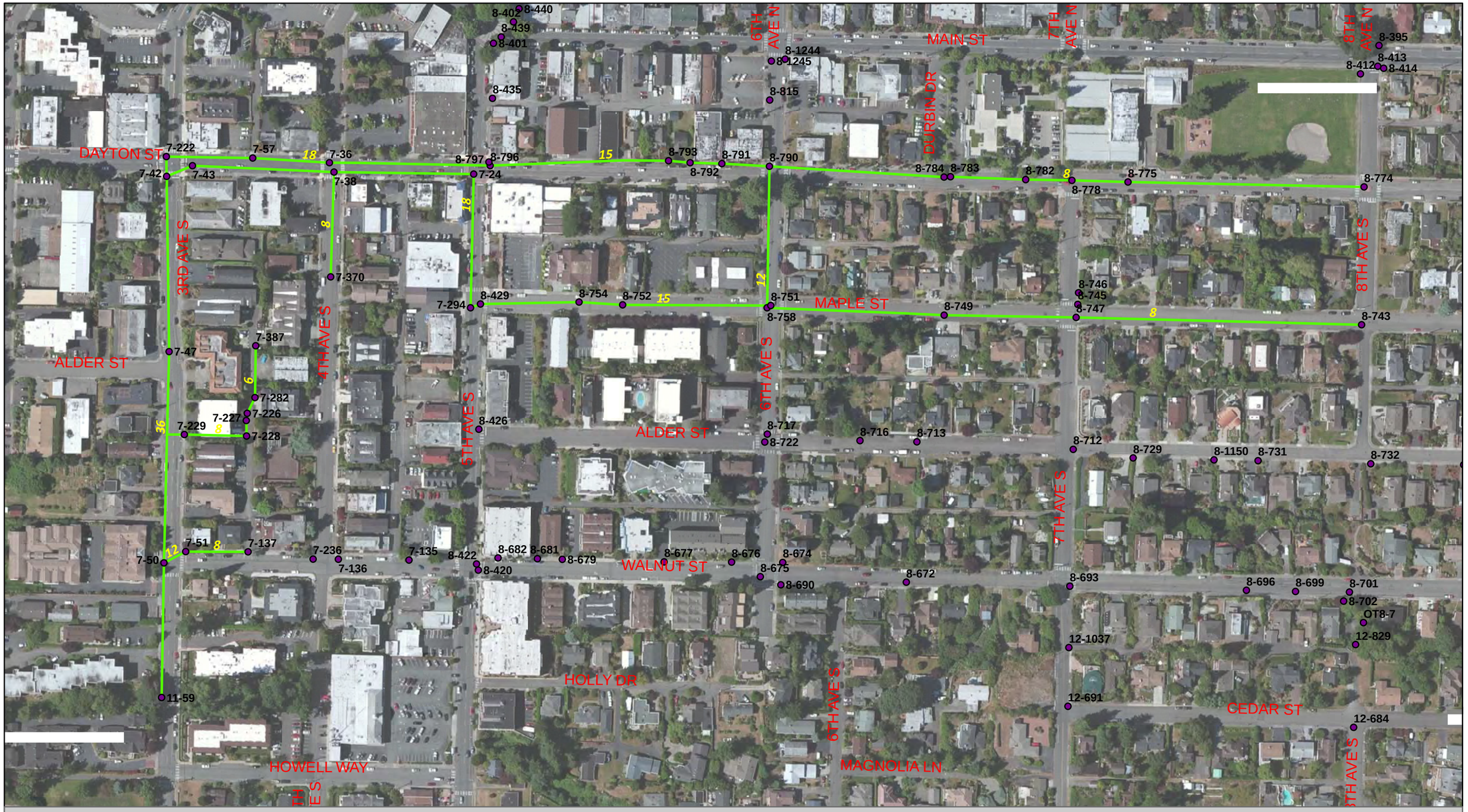




Figure 2-4
Primary System Modeled

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Design storms for the existing system analysis were selected with City input. The SCS 24-hour Type 1A rainfall distribution was used along with the 2-, 10-, 25- and 100-year 24-hour rainfall totals for the project location from the NOAA isopluvial maps. These design events have been traditionally used in the Pacific Northwest for event based modeling. The 24-hour precipitation amounts are given below:

Table 2-1:
24-Precipitaiton Amounts

| Design Event | 24-hour Precipitation (inches) |
|---|---|
| 2-year | 1.4 |
| 10-year | 2.1 |
| 25-year | 2.5 |
| 100-year | 3 |

It was noted that the August 29th storm event was a very intense summer thunderstorm. Per City staff, the precipitation was measured at 1.75 inches of rain in less than 2 hours. This is beyond the typical design event in the Pacific Northwest. For comparison, the peak 2.2 hours for the 25-year 24-hour SCS type 1A storm is only 0.65 inches. Another comparison is that the 100-year 6-hour storm from NOAA isopluvial maps is 1.5 inches for the entire 6 hour event. Thus, in 2 hours the August 29th storm event exceeded the 6-hour 100-year design event. Copies of isopluvial maps for the four return periods analyzed are shown in Attachment A-1.

The Santa Barbara Unit Hydrograph (SBUH) method was used for hydrologic analysis in XPSWMM. The main input parameters with this method are:

- The drainage area. This was obtained from GIS.
- The impervious percentage of the subbasin. This was calculated using the zoning GIS data made available by the City using assumed percent impervious land cover within each zoning category. These calculations are included in Attachment A-2.
- The SCS Curve Number for pervious areas within the subbasin. This was obtained using the soil data from GIS. The drainage area soils consist of Alderwood Urban Land Complex (Hydrologic group C), Everett Gravelly Sand Loam (Hydrologic groups A/B), and Kitsap Silt Loam (Hydrologic group C). The curve number for open space, lawn, and landscaping in fair condition was used in the study area (90 for all subbasins except 85 for 4, 5, 6, 7 and 14 where there is a significant percentage of Everett Gravelly Sand Loam).
- The time of concentration. This was obtained by calculating the travel times for sheet flow, shallow concentrated flow and pipe flow within each subbasin (i.e., procedures following guidance in the King County Stormwater Design Manual). These calculations are included in Attachment A-3.

It was also noted during the field reconnaissance, that there was significant base flow in some of the pipe systems. There are short sections of flowing small drainage/creeks in the upper basin that are fed by groundwater in addition to precipitation and they connect to the pipe network. In consultation with the City, it was decided to conduct a site visit and estimate the system base flow in a few locations. This was done on April 2, 2014, after three days of no rain preceded by a few days of moderate to heavy precipitation. Approximate base flows were estimated by measuring depths in the pipes and comparison with normal flow equations. The results were as follows:

Table 2-2:
Estimated Base Flows

| Location | Pipe Size (in) | Estimated Flow (cfs) |
|---|---|---|
| 3rd Ave S and Dayton St (36" pipe, at the channel of the manhole, model node 750) | 36 | 2.3 |
| 6th Ave S and Dayton St (12" pipe to West, model node 8-790) | 12 | 1.4 |
| 6th Ave S and Maple St (15" pipe to West, model node 8-751) | 15 | 0.8 |

These flow estimates were calculated using Manning's equation for partial full pipe analysis. This approach was considered reliable for the 36-inch diameter system on 3rd Ave S because it is channelized through the manhole and at uniform slope. There was some uncertainty about using this method at the other locations, because the catch basins are not channeled, and the catch basin headloss may affect the results. To check the calculations a simple one-pipe SWMM model was developed for each and the results closely matched those using the partial pipe flow analysis. Thus, the results were considered reasonable for this analysis.

A comparison was then made between these base flow estimates and the predicted storm flows during the 25-year event. The result was that the percentage of base flow compared to the storm flow ranged between 5 percent (at 3rd Ave S and Dayton St) to 13 percent (at 6th Ave S and Dayton St). Given the relatively high percentage of base flow to storm flow, particularly in the upper basin where the pipe sizes are smaller, it was determined that adding base flow to the model is appropriate. The flow estimate at 3rd Ave S and Dayton St was considered the most reliable because it mostly reflected normal flow hydraulics, so it was used as the flow input to the model. Flows were distributed as follows:

Table 2-3:
Added Base Flows

| Location | Model Node | Base Flow Added (cfs) |
|---|---|---|
| 8th Ave S and Dayton St | 8-774 | 0.37 |
| 8th Ave S and Maple St | 8-743 | 0.37 |
| 7th Ave S and Dayton St | 8-778 | 0.37 |
| 7th Ave S and Maple St | 8-747 | 0.37 |
| 6th Ave S and Dayton St | 8-774 | 0.37 |
| 6th Ave S and Maple St | 8-743 | 0.37 |

The calculations for the base flow estimates and results are presented in Attachment A-4. (Noted that the location for the base flow input into the model was modified for the Expanded Subbasin Plan as described in Section 3).

Pipe information for the hydraulic analysis was mostly obtained from the City's GIS data. Generally, the existing pipes are concrete and a roughness coefficient of 0.013 was used. For existing conditions modeling, the roughness coefficient for the pipe on 4th Ave S was increased because this pipe was TV'd and it was found that the wall of the bottom half consisted of rough aggregates. Similarly, the existing pipe from the alley west of 4th Ave S to 3rd Ave S was given a higher roughness to account for multiple root intrusions, sags and bends which were found by TV'ing the pipe.

Overflow paths consisting of a typical curb/gutter cross section (12-foot lane, cross slope of 2 percent and a 6-inch high curb) were used to model surface overflows along the gutter line in between catch basins. These overflow paths were added to all pipe segments on Dayton St and Maple St.

On-site detention was not included in the model analysis. This is because a significant portion of the existing development was constructed before detention standards became a requirement and because on-site storage systems sized using past methods are typically undersized and become overwhelmed during significant flood events.

## 2.4 Existing Conditions Modeling and Level of Service Assessment

The XPSWMM model was run for the existing drainage system within the study area. The four return period storms of 2, 10, 25 and 100 years were simulated in order to assess the level of service provided by the existing pipe system. The results of this analysis are presented on Figure 2-5 where the pipes are color coded to reflect their level of service. The level of service was determined based on the storm at which there would be surface overflows (i.e., stormwater exceeds the capacity of the pipe system and

overflows into the roadway gutter). For example, a level of service of "< 10 year" signifies that surface overflows are simulated during the 10-year storm. Model output summaries are included in Attachment A-5.


## Pipe Level of Service Legend

< 2 Year
< 10 Year
< 25 Year
< 100 Year
>100 Year

## Legend (Other Items)

Storm Pipe or Channel
(Not Modeled in SWMM)

N

1 inch = 200 feet

0 100 200 400 Feet

Figure 2-5
Existing Level of Service

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The following conclusions can be drawn from this analysis:

1. The existing drainage system is generally undersized because there are many portions that do not provide a 10-year level of service. A typical design standard for drainage systems is to contain the 25-year design storm within the pipe system and contain the 100-year design storm within the roadway section (King County). The City's current standard for new development is to contain flows (no surcharging) for the 50-year event (Section 4.10.2 of the Stormwater Code Supplement to Edmonds Community Development Code Chapter 18.30).

2. Flooding Area 2, the low point along 4th Ave S has the lowest level of protection and is simulated to flood at less than the 2-year event. This is consistent with reported conditions. The low area ponds and overflows west to overwhelm the drainage system in the alley. However, it was determined that if the 4th Ave S system could be contained and not overflow to the west, the alley system would have 100-year level of protection. The modeling of the alley system incorporated the recent system upsizing to 8 inches in 3rd Ave S.

3. The modeling results show that the system at 5th Ave S and Maple, Flooding Area 3 floods at less than the 25-year event and that the system at 5th Ave S and Dayton, Flooding Area 4 floods at less than a 10-year event.

   Note that the modeled depth of overflow between Maple St and Dayton St is 0.15-0.25 ft during the 25-year storm. These depths are lower than the level of flooding observed on August 29th, 2013, due to the different rainfall distribution and intensity of rainfall. If a rainfall distribution that represents an intense short duration thunderstorm would be used, the depths of flooding would be much more significant and closer to the observed depths on August 29th.

4. Flooding Area 5, along Dayton St west of 7th Ave S is simulated to have less than a 10-year level of protection (nodes 8-782 to 8-791). This portion of the system consists of 8-inch diameter concrete pipes from node 8-782 to 8-790 and a 12-inch concrete pipe from node 8-790 to 8-791. The City indicated that this system is subject to root intrusion which was not accounted for in the modeling. Therefore, flooding could occur even more frequently. Downstream of node 8-791 (west of 6th Ave S), the capacity improves significantly as the pipe diameter increases to 15 inches and the level of service increases to the 100-year storm.

5. There is a lack of capacity in the 8-inch and 12-inch pipes along Maple St between 6th Ave S and 7th Ave S from node 8-751 to node 8-747. This segment of the drainage system drains a 32.5-acre area which is a large area to be drained by an 8-inch pipe. The two pipe systems downstream also are simulated to have a level of protection less than the 10-year event.

6. As noted previously, during the field reconnaissance a lack of storm drain inlets along some streets was observed. An example is the long block along Maple St between 8th Ave S and 9th Ave S. In these situations, it is likely that during heavy precipitation gutter flow exceeds the inlet capacity of the catch basins that are present resulting in overflows that continue downslope.

## 2.5 Alternative Identification

Following discussions with City staff regarding the existing system level of service and flooding area problems, Louis Berger staff developed a preliminary list of flood reduction options for City review. Following City review and input a final list of options was developed for detailed analysis. These options were put into three separate categories; Primary System Improvement Alternatives, Subbasin-Wide Improvements, and 4th Ave S Early Action Alternatives. These options are briefly described below and further evaluated in the subsequent paragraphs.

*Primary Conveyance System Alternatives* – Three alternatives were identified to increase the level of protection for the primary conveyance system within the subbasin (i.e., the system that was modeled).

1. Primary System Alternative 1 – Pipe Replacements to Achieve 25-year Level of Protection. This includes replacing pipes that do not provide 25-year level of protection with larger diameter pipes until the 25-year level of protection is achieved. The 25-year level of protection was defined as flows needing to be contained within the pipe system (i.e., not overflow in the gutter).

2. Primary System Alternative 2 – Pipe Replacements to Achieve 50-year Level of Protection. This includes replacing pipes that do not provide 50-year level of protection with larger diameter pipes until the 50-year level of protection is achieved. The 50-year level of protection was defined as flows needing to be contained within the pipe system (i.e., not overflow in the gutter).

   The 50-year 24-hour precipitation is 2.71 inches (8 percent higher than the 25-year 24-hour precipitation). This option was included as a separate alternative because it may not require much increase in pipe size and associated costs to provide a larger level of protection.

3. Primary System Alternative 3 – Pipe Replacement and Relocations to Achieve 50-year Level of Protection. This option is similar to Alternative 2, but it includes modifying the locations for the pipe replacement to assess whether there would be advantages to rerouting some of the flow along certain City blocks.

One option that was identified initially, but later rejected, included a major re-routing of a portion of the basin. The idea was to construct a new storm system that would route flows from the intersection of Alder St and 7th Ave W west to 5th Ave S and then south to Walnut St and then west to 3rd Ave S. This could roughly divert approximately one-third of the basin away from the undersized existing system. It was thought that by doing this, a large portion of the existing system would not need to be replaced. However, when it was investigated further, it had two major disadvantages. First, there would be a section of the alignment between 5th Ave S and 6th Ave S that would be so deep (on the order of 25 feet) that the construction technique would likely require trenchless technology such as directional drilling. Second, it was concluded that even though a large portion of the basin would be diverted, much of the system along Dayton Ave S would still need to be replaced and, as such would not cut down the overall length of needed pipe improvements, rather it would require more overall pipe improvements. For these reasons, this option not considered for detailed analysis.

*Subbasin Wide Alternative* – Only one alternative was identified that would help improve the general drainage collection system within the subbasin.

- Subbasin Wide Alternative 1 – Implement Program to Add Catch Basins/Inlets. As noted previously, one of the study observations was the lack of catch basins/inlets within the basin, particularly in the northeast portion of the basin. Typical desired maximum spacing is on the order of 300 feet. Several of the long, east-west oriented blocks are 600 feet long and do not have a mid-block catch basin. This option includes identification of locations where additional inlets would be beneficial. In some of these locations, there would also need to be a system pipe extension to the proposed location of the catch basin.

*4th Ave S Early Action Alternatives* – The intent of this category was to identify the best approach to eliminate or reduce the flooding Problem Areas 1 and 2 when considering the City's desire to construct an early action conveyance improvement. An initially concept to solve flooding at Problem Area 1 was to construct a new storm system along the alley between 3rd Ave S and 4th Ave S south to Walnut Street and then west to Alder St, and for Problem Area 2 to replace the system in 4th Ave S with a larger diameter pipe. However, following some of the initially modeling of the Primary Conveyance System Alternatives, the following observations were made:

- Flooding Problem Area 1 is caused by overflows from Flooding Problem Area 2. That is, water levels rise above the road grade along the low point along 4th Ave S (between Dayton St and Walnut St) and overflow west through private property to reach the alley and flood other private properties. The modeled overflows have been confirmed through City conversations with local residents. The overflows occur on a relatively frequent basis.

- If the overflows from Flooding Problem Area 2 can be eliminated, it would reduce the flooding at Problem Area 1. A simple hydraulic model was developed for the small private system that extends from midblock in the alley between 3rd Ave S and 4th Ave S and extends west directly to 3rd Ave S (see Figure 1). The simple model showed that if this system did not receive overflows from the 4th Ave S, it would be able to contain the 100-year event.
- To reduce flooding along 4th Ave S, a pipe system replacement along 4th Ave S alone would help reduce flooding but would not provide up to the 25-year level of protection. This is because the pipe system in Dayton St is undersized. Therefore to fully improve this problem, the pipe system would need to be constructed together with the primary conveyance system alternatives.

  Thus, it was decided with City input to move forward with one alternative for Flooding Problem 1 and 2, referred to as 4th Ave S Alternative 1, which includes a pipe system upgrade along 4th Ave S to Dayton St and ties into the preferred alternative under the primary conveyance system alternatives.

## 2.6 Alternative Analysis

The following paragraph further describes the alternative options and their development:

*Primary System Alternative 1 – Pipe Replacements to Achieve 25-year Level of Protection*

As noted above, this alternative includes replacing pipes that do not provide 25-year level of protection with larger diameter pipes until the 25-year level of protection is achieved. It is noted that the City uses the 50-year standard for new development (excerpted from the downstream analysis requirements, Section 4.10.2). However, the 25-year level of protection is a pretty typical conveyance standard and it seemed appropriate to consider this standard for a retrofit situation.

The SWMM hydraulic model was used to determine what pipe replacement sizes would be needed to provide the 25-year level of protection. In general, existing pipes that were undersized and did not provide the 25-year level of protection were upsized in the model until all flow was contained within the system for the 25-year event. One exception to this is that at the intersection of 5th Ave S and Dayton St, a new pipe was included to connect the existing 18-inch on the north side of the street with the new 24-inch on the south side of the street. The reason for this it to eliminate the need to replace the systems on both the north and south side of the street west of 5th Ave S.

The resulting pipe replacements are shown on Figure 2-6. This figure shows the replacement pipe sizes and model nodes. SWMM model results for this alternative as well as other alternatives are contained in Attachment A-5. In summary, the pipe system improvements include the following:

- Pipe System Replacement with 12-inch Diameter Pipe: 1322 LF
- Pipe System Replacement with 18-inch Diameter Pipe: 940 LF
- Pipe System Replacement with 24-inch Diameter Pipe: 1730 LF

Note that this alternative results in a "downsizing" of pipe sizes at one location. Normally pipe sizes increase as the system extends downstream because of increasing flows. However, where there is a large increase in pipe slope and consequently pipe capacity, a smaller downstream pipe diameter may have sufficient capacity. "Downsizing" of pipe sizes is sometimes a concern because of the potential for trapping materials due to the pipe size reduction. At the same time, this concern is often outweighed by the cost savings by allowing the downsizing. Under this Alternative, along Maple St between 5th Ave S and 6th Ave S, the pipe size drops from a 24-inch diameter to a 15-inch diameter, where the existing 15-inch is very steep and can carry the design flow.

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## Legend

- SWMM Nodes
- Pipes Added/Upsized
- Existing Pipes
- Existing Pipes Not Modeled in SWMM

N

1 inch = 200 feet

0 100 200 400 Feet

Figure 2-6
Primary System Alternatives 1 and 2 Improvements

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*Primary System Alternative 2 – Pipe Replacements to Achieve 50-year Level of Protection*

This alternative is very similar to Alternative 1. To determine the required pipe sizes to provide 50-year level of protection, the Alternative 1 model was used initially and it was found that only one section of pipe needed to be upsized. This section of pipe was along Dayton St between 4th Ave S and 3rd Ave S.

The resulting pipe replacements are shown on Figure 2-6 (Figure 2-6 shows both Alternative 1 and Alternative 2). In summary, the pipe system improvements include the following:

- Pipe System Replacement with 12-inch Diameter Pipe: 1322 LF
- Pipe System Replacement with 18-inch Diameter Pipe: 940 LF
- Pipe System Replacement with 24-inch Diameter Pipe: 1353 LF
- Pipe System Replacement with 30-inch Diameter Pipe: 377 LF

A cost estimate was developed for this alternative. The cost estimate for this alternative is $2,163,000. Cost estimates include construction, a construction contingency of 30 percent, and soft costs (i.e., 30 percent for survey, design, and permitting, 5 percent administration, and 15 percent for construction management and inspection). The detailed cost estimate development is included in Attachment D.

Recognizing that only one section of pipe (377 feet) needed to be larger pipe diameter in order to provide the higher level of protection for Alternative 2, it is reasonable to prefer this alternative to Alternative 1. For this reason, no cost estimate was developed for Alternative 1.

*Primary System Alternative 3 – Pipe Replacement and System Realignment to Achieve 50-year Level of Protection.*

As noted above, this option is similar to Option 2, but it includes modifying the locations for pipe improvements to assess whether there would be advantages to realignment some of the pipe improvements along other City blocks. The alignment for pipe improvements under this alternative is shown on Figure 2-7. The main alignment change is to make pipe system replacements along 6th Ave S between Maple St and Dayton St rather than along 5th Ave S and add a system along the south side of Dayton St between 5th Ave S and 6th Ave S. Thus, there would be a parallel system along Dayton St between 5th Ave S and 6th Ave S. These improvements are intended to divert the flows from subbasins 2, 3, and 14 into the new pipe on Dayton St and eliminate the potential for these flows to drain to flooding problem area 3. Subbasin 5 would still drain to the system on Maple St. Overall, this Alternative eliminates the need to replace about 300 feet of pipe.

In summary, the pipe system improvements include the following:

- Pipe System Replacement with 12-inch Diameter Pipe: 1322 LF
- New 12-inch Pipe (across the intersection of Dayton St and 5th Ave S): 40 LF
- Pipe System Replacement with 18-inch Diameter Pipe: 293 LF

- Pipe System Replacement with 24-inch Diameter Pipe: 1330 LF
- New 24-inch Pipe: 660 LF
- Pipe System Replacement with 30-inch Diameter Pipe: 62 LF

An advantage to this alignment is that it reduces the extent of construction work on 5th Ave S, which is one of the City's main arterials. Another advantage of this alignment is that, unlike Alternatives 1 and 2, it does not result in the pipe system "downsizing" along Maple St. The cost estimate for this alternative is $2,084,000.

Connect system on north side to new 24" SD on south side (12" pipe connection)

Eliminate flow split so that all flow from Maple St system goes north, and all flow from 6th Ave S system goes west

## Legend

- Nodes
- Pipes Added/Upsized
- Existing Pipes
- Existing Pipes Not Modeled in SWMM

N

1 inch = 200 feet

0 100 200 400 Feet

Figure 2-7
Primary System Alternative 3 Improvements

Louis Berger

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*Subbasin Wide Alternative 1 – Program to Add Catch Basins/Inlets*

This alternative reflects more of a general system improvement rather than to address a specific problem area. It includes a program to add additional curb inlets along those portions of streets where the spacing between catch basins is large or spans the whole length of the block. It can be considered independent of the primary system alternatives and thus added to any of the above alternatives. The insufficient number of inlets was observed during the November 2013 site visit. One resident on Dayton St near 8th Ave S confirmed that the gutter flow at the end of the long block was so deep that it would overwhelm the catch basin at the end of the block and overflow the street to the west. No modeling was done to analyze this alternative. Rather, a mapping exercise was completed using the City's GIS maps showing the drainage system to identify long blocks where there appeared to be a lack of catch basins. A typical maximum design spacing for catch basins is 300 feet (less at flat grades). Using the maps, the locations of the additional catch basins were identified. In many cases, storm drain pipe extensions would be needed in order to connect the catch basins to the system (typically to a midblock location). Figure 2-8 shows the proposed additional inlets and pipes. The flood reduction benefits of these improvements were not quantified but it can be assumed that these inlets would help capture gutter flow and reduce the potential for excessive water ponding at intersections.

In summary, the pipe system improvements include the following:

- 22 Catch Basins (Type 1)
- Pipe System Improvements with 8-inch Diameter Pipe: 350 LF (assumed for laterals)
- Pipe System Replacement with 12-inch Diameter Pipe: 700 LF (assumed for non-laterals)

The cost estimate for this alternative is $572,000.

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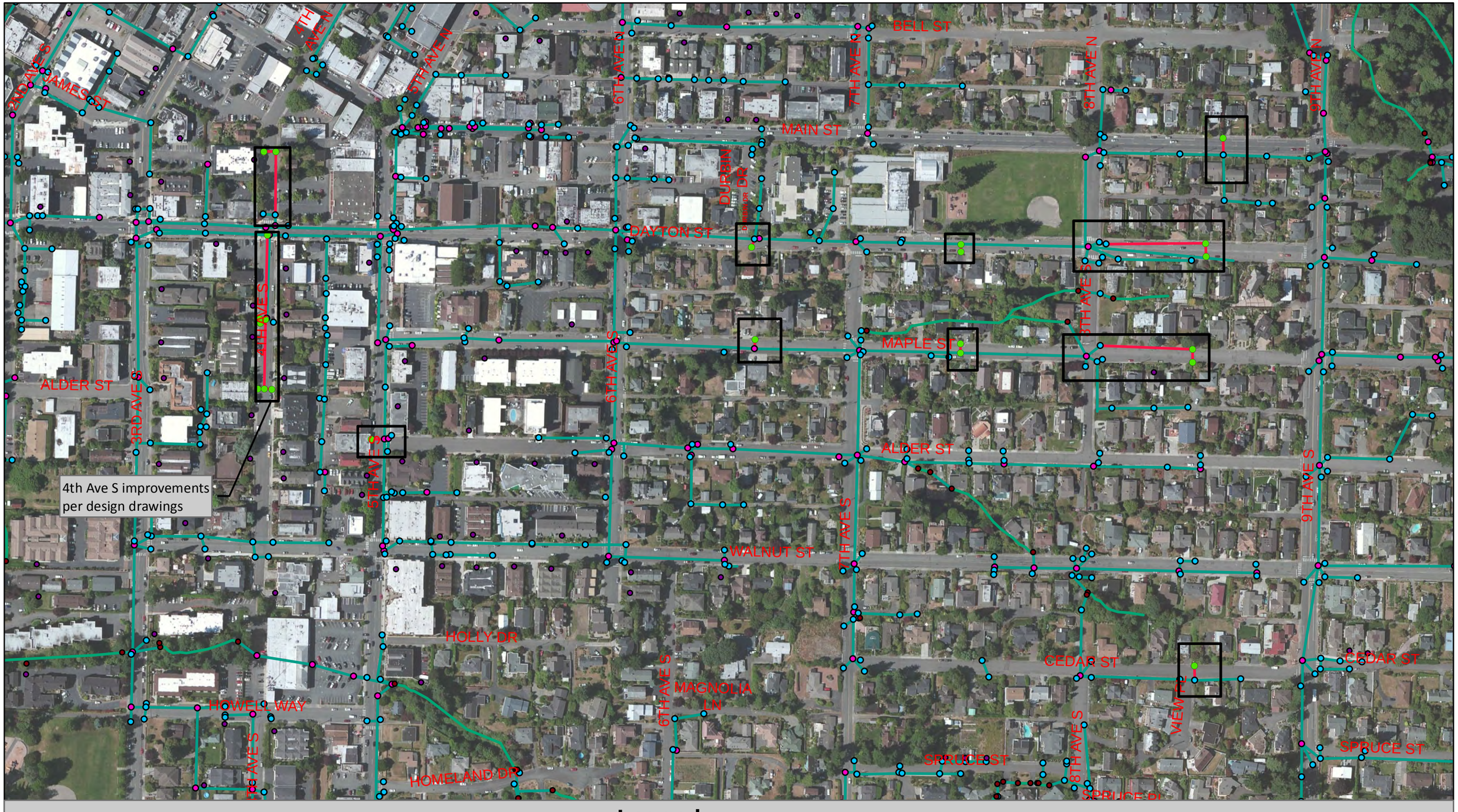


## Legend

N

1 inch = 250 feet

0 125 250 500 Feet

- Existing Storm Catch Basin Type 1
- Existing Storm Catch Basin Type 2
- Proposed CB
- Proposed Pipe
- Existing Storm Pipe or Channel

Figure 2-8
Subbasin Wide Alternative 1 Improvements

Louis Berger

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*4th Ave S Early Action Alternative 1*

As discussed above, this alternative includes a pipe system improvement along 4th Ave S to convey runoff to Dayton St. Because the City had developed survey base maps of 4th Ave S with the idea of implementing an early action project, this information was available to complete a more detailed design of the alternative. A plan and profile of the proposed alternative is presented in Figure 2-9. Additional details about the proposed improvement are noted below.

- 4th Ave S between Walnut St and Dayton St is one of the long blocks at approximately 900 and having only one set of catch basins at the low point. Thus, a pipe extension and a second set of catch basins south of where the current system exists was included in the design.
- The pipe diameter for the new system is 12-inch diameter, increased from 8-inch diameter for the existing pipe.
- An additional set of catch basins is also recommended at the low (sag) point of the road. These can act as secondary inlets at low points if the first set becomes clogged with debris/leaves.
- A short section of asphalt berm (i.e., similar to a speed bump in a parking lot) along the west side of the road at the back of the driveway to the Avalon at Edmonds condominiums is also proposed. This is the low point of the road, where stormwater runoff can leave the road and flow unto private property during significant flood events. Adding a low height berm will provide additional freeboard prior to when roadway overtopping would occur. This also provides some additional flood protection until such time as the primary system improvements are implemented along Dayton St. As noted previously, the pipe system replacement alone would help reduce flooding but would not provide up to the 25-year level of protection. This is because the pipe system in Dayton St is undersized.

The cost estimate for this alternative is $123,160. Note that this system was constructed in the summer of 2014.

## 2.7 Recommendations and Implementation

For the Primary Conveyance System Alternatives, Alternative 3 is recommended. Alternative 1 is not recommended, because for a small increase in upsizing one reach of pipe, the City can get a 50-year level of protection. Alternative 3 is recommend over Alternative 2 because of cost savings and reduced impacts to 5th Ave S. For the Subbasin Wide Alternative, only Alternative 1 was considered and it is recommended that the City implement this alternative (i.e., as opposed to a no action alternative). The additional inlets will increase the collection system performance and reduce the extent of catch basins being overwhelmed and associated street ponding. For the 4th Ave S Early Action Alternative, it is recommended to implement the pipe system improvements as an early action improvement. It is noted that this work will help reduce flooding (roughly up to a 10-year level of protection), but additional level of protection will not be achieved until the downstream portion of Primary System Alternative 3 is implemented (along Dayton St).

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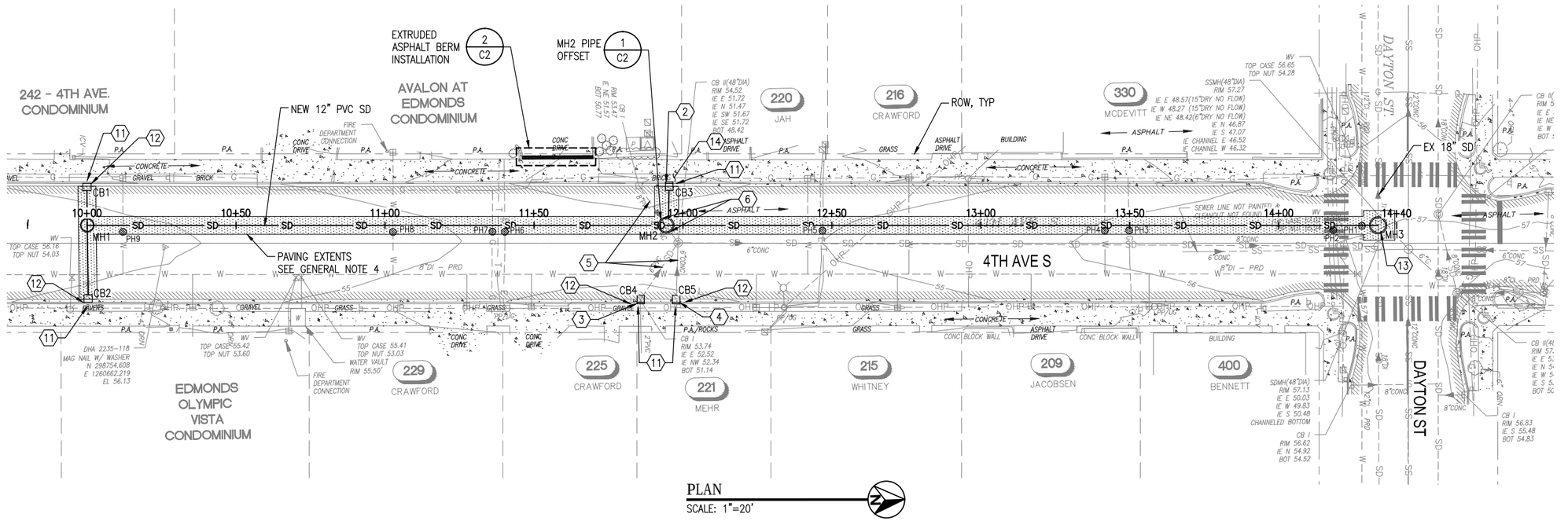
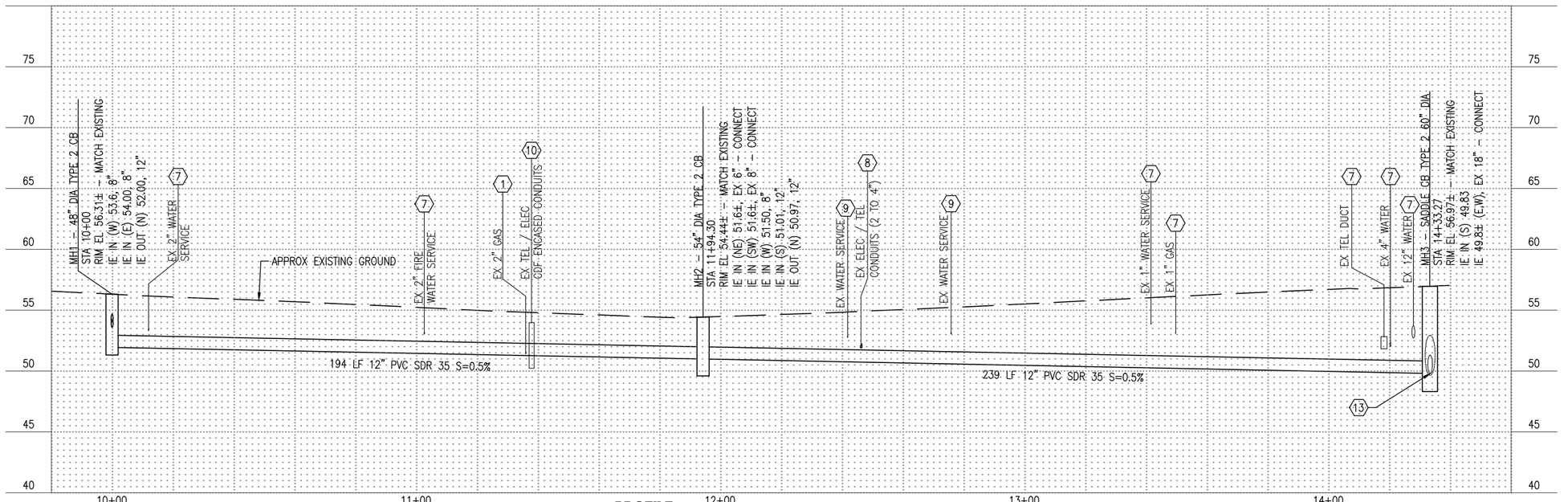



PLAN
SCALE: 1"=20'




PROFILE
MH1 TO MH3
HORZ SCALE: 1"=20'
VERT SCALE: 1"=5'

1"=20' Scale 20 10 0 20 40 Feet
1"=5' Scale 5 2.5 0 5 10 Feet

## GENERAL NOTES

1. CONTRACTOR SHALL LIMIT DISTURBANCE TO 4TH AVE S TO THAT NECESSARY TO CONSTRUCT PROPOSED STORMWATER IMPROVEMENTS. FOLLOWING THE INSTALLATION OF THE NEW SD, CONTRACTOR SHALL RESTORE THE ROADWAY TO ITS EXISTING GRADE.
2. SEE STRUCTURE SCHEDULE ON DWG C2.
3. TRENCH SECTION SHALL BE PER CITY OF EDMONDS STANDARD DETAIL E4.2 ON DWG C3.
4. PAVING EXTENTS SHALL BE PER CITY OF EDMONDS STANDARD DETAIL E2.3 ON DWG C3.
5. SEE POTHOLE SUMMARY TABLE ON DWG C2.
6. PRIOR TO ORDERING MATERIALS, CONTRACTOR SHALL POTHOLE AND DETERMINE EXACT UTILITY LOCATIONS AND DEPTHS AT STA 11+40. SEE CONSTRUCTION NOTE 10 THIS SHEET.

## CONSTRUCTION NOTES

1. EXISTING GAS IS IN CONFLICT WITH NEW STORM. CONTRACTOR SHALL EXPOSE GAS DURING TRENCHING ACTIVITIES AND COORDINATE WITH PSE WHO WILL RELOCATE GAS WHILE THE EXCAVATION IS OPEN. IF NEEDED EXPAND TRENCH WIDTH AT THIS CROSSING IF REQUESTED BY PSE. COORDINATE THIS WORK WITH PSE.
2. INSTALL TYPE 1 CB WITH THRU-CURB INLET. POTHOLE EXISTING GAS TO CONFIRM THAT THERE WOULD BE NO CONFLICT. SEE PROFILE ON DWG C2.
3. REPLACE EXISTING CB WITH NEW TYPE 1 CB WITH THRU-CURB INLET. CONNECT TO EXISTING PIPES AND REPAIR ASPHALT AROUND CB.
4. INSTALL TYPE 1 CB WITH THRU-CURB INLET. CONNECT TO EXISTING PIPES AND REPAIR ASPHALT AROUND CB.
5. CLEAN EXISTING LATERALS TO REMAIN.
6. CONNECT EXISTING 8" PVC (WHICH TRANSITIONS TO A 6" CONC) SD TO MH2.
7. CONTRACTOR TO PROTECT UTILITY AND PROVIDE TEMPORARY SUPPORT DURING CONSTRUCTION.
8. POWER AND TEL CONDUITS ARE CLOSE TO TOP OF PIPE. CONTRACTOR TO EXERCISE CAUTION IN THIS AREA AND PROTECT THESE CONDUITS.
9. EXISTING WATER SERVICE CROSSING HAS NOT BEEN POTHOLED. CONTRACTOR TO POTHOLE. IF IN CONFLICT WITH NEW STORM, CONTRACTOR SHALL REMOVE AND REINSTALL SERVICE CONNECTION. WORK SHALL BE PAID FOR AS UNFORESEEN CONDITIONS.
10. NEW STORM CROSSES TEL AND POWER WHICH ARE ENCASED IN DEEP CDF TRENCH (AT LEAST 4.5' DEEP). ACTUAL DEPTH OF UTILITIES WITHIN ENCASEMENT IS UNKNOWN. CONTRACTOR TO COORDINATE WITH PRIVATE UTILITIES (COMCAST, SNO CO PUD, FRONTIER, OTHERS) AND CHIP OUT CDF AROUND THE VERTICAL ALIGNMENT OF THE NEW STORM TO DETERMINE IF PRIVATE UTILITY RELOCATION IS REQUIRED. IF SO CONTRACTOR SHALL COORDINATE RELOCATION WITH UTILITIES. THIS MAY REQUIRE ADDITIONAL CDF REMOVAL.
11. REPAIR CURB AND GUTTER DAMAGED BY INSTALLATION OF CB PER CITY OF EDMONDS STANDARD DETAIL E2.8.
12. RESTORE BUFFER STRIP BETWEEN CURB AND SIDEWALK IN KIND IF DAMAGED BY THE INSTALLATION OF CB.
13. INSTALL MH3 (TYPE 2 – 60" SADDLE TYPE CB) AND CONNECT TO EXISTING 18" SD. SADDLE TYPE CATCH BASIN SHALL BE DESIGNED WITH 36" WIDE SADDLE OPENING TO ALLOW FOR FUTURE REPLACEMENT OF 18" SD (EAST/WEST) WITH 24" SD. BOTTOM ELEVATION OF CATCH BASIN TO BE 47.3.
14. RESTORE ANY DAMAGED BRICK WORK IN KIND IN THIS AREA.

CALL 48 HOURS BEFORE YOU DIG 1-800-424-5555

Farah, Joe [RA] – 7/9/2014 4:56 PM – \\1798u-appcv01\Project\Temp\Edmonds\Final Design\C1 STORM PIPELINE PLAN AND PROFILE.dwg

MICHAEL S GILBERT STATE OF WASHINGTON 24055 REGISTERED PROFESSIONAL ENGINEER 7-9-14

DESIGNED JF
DRAWN ABG
VERIFY SCALE BAR IS ONE INCH ON ANSI "D" DRAWING 0 1"

| REV | DATE | CHK'D | APP'D | REVISION DESCRIPTION |
|---|---|---|---|---|
| – | 6/13/14 | MSG | MSG | BID SET |

City of Edmonds
Engineering Division
121 5th Avenue North
Edmonds, WA 98020
(425) 771-0220

Louis Berger

**Figure 2-9**

4TH AVE S STORM MAIN PIPELINE PLAN AND PROFILE

SCHEDULE A

PROJECT NUMBER: E4FA / C433
SHT. 3 OF: 10
DRAWING NUMBER: C1

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In terms of implementation, the Primary System Alternative 3 was divided into smaller projects that would be easier to be prioritized and integrated into the City's annual capital improvements program. The priority for implementation is generally based upon constructing improvements from downstream to upstream sequence, but also takes into account addressing the known flooding problems first.

In terms of the program to add additional catch basins, it is recommended that this be worked into the City's ongoing small works construction program by City staff or small contracted projects as City resources allow.

The following table lists the priorities and project costs. Figure 2-10, Recommended Plan, shows these projects and reflects all of the recommended projects from the alternative evaluation.

Table 2-4:
Project Descriptions and Costs

| Priority | Project ID - Name | Description | Cost |
|---|---|---|---|
| 1 | 4th Ave S Improvements | Construct 433 LF 12-inch Storm Drain along 4th Ave South and connect to Dayton St | $123,160 |
| 2 | Primary System (PS) Alt. 3 – Project 1 | Replace System Along Dayton from 3rd Ave S to 5th Ave S | $464,000 |
| 3 | Primary System (PS) Alt. 3 – Project 2 | Construct Parallel System Along Dayton from 5th Ave S to 6th Ave S | $377,000 |
| 4 | Primary System (PS) Alt. 3 – Project 3 | Replace System Along Dayton from 6th Ave S to 8th Ave S | $649,000 |
| 5 | Primary System (PS) Alt. 3 – Project 4 | Replace System Along 6th from Dayton to Maple and along Maple from 6th Ave S to 7th Ave S | $594,000 |
| Annual | Subbasin Wide Alternative 1 | Install additional inlets where needed in basin | Overall Cost is $572,000 (to be implemented as resources allow) |

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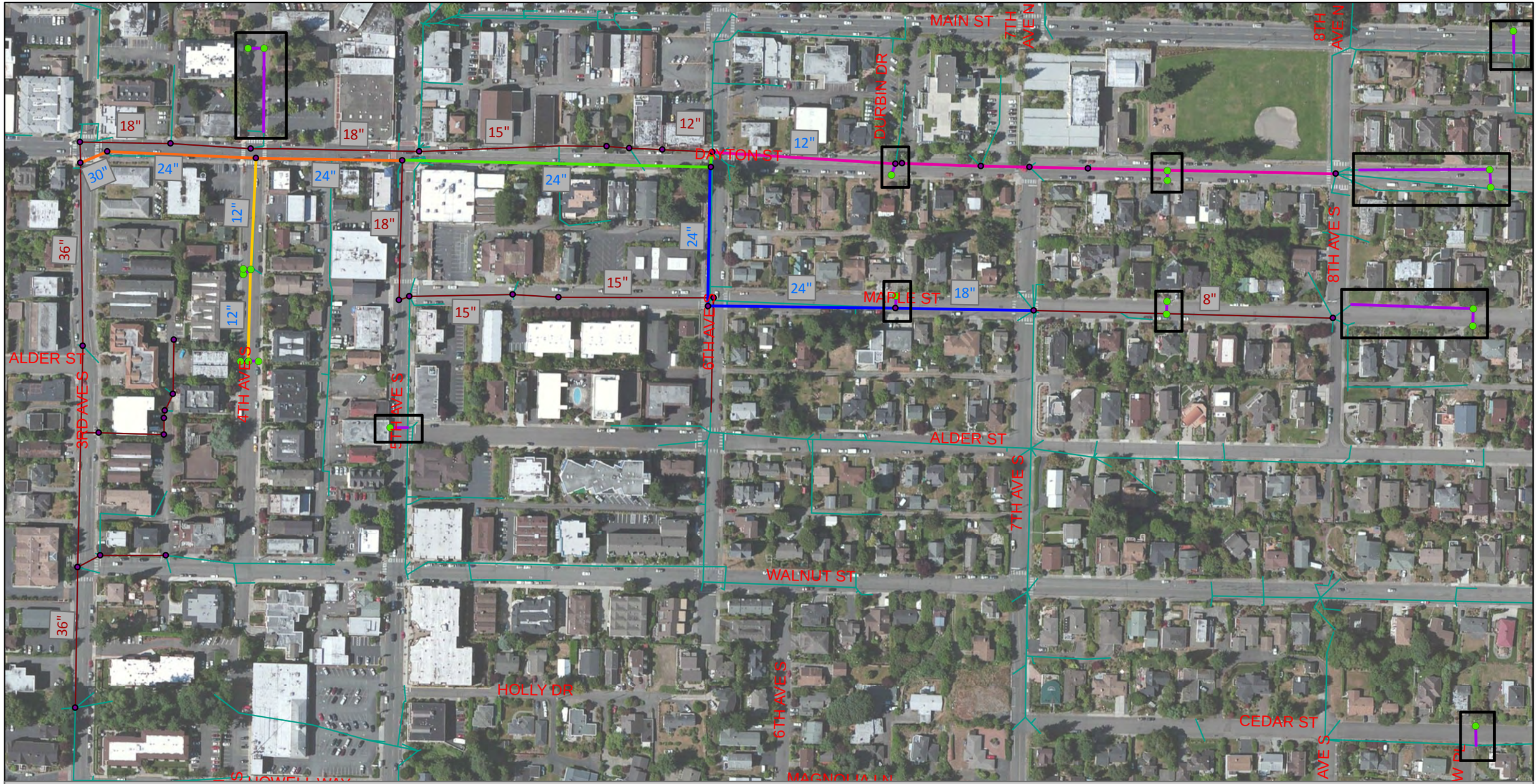


## Legend

- 4th Ave S Improvements - Priority 1
- Primary System Project 1 - Priority 2
- Primary System Project 2 - Priority 3
- Primary System Project 3 - Priority 4
- Primary System Project 4 - Priority 5
- Proposed CB for Inlet Improvments
- Proposed Pipe for Inlet Improvements
- Nodes
- Existing Pipes
- Existing Pipes Not Modeled in SWMM

N

1 inch = 200 feet

0 100 200 400 Feet

Figure 2-10
Recommended Plan

Louis Berger

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The following section provides some additional descriptions of the recommended Alternative 3 projects in their order of priority.

*Alternative 3 Project 1*

This project consists of replacing approximately 687 LF of 18-inch diameter storm drain with 625 LF of 24-inch diameter and 62 LF of 30-inch diameter storm drain on the south side of Dayton St between 3rd Ave S and 5th Ave S. These improvements would require a minimum of three new Type 2 catch basins. It is possible that additional catch basins may be necessary to pick up lateral connections. Note that the 60-inch diameter catch basin to be installed at the intersection of 4th Ave S and Dayton St as part of the 4th Ave S drainage improvements was sized to accommodate the new 24-inch diameter pipe. As noted previously, Project 1 would fully resolve the flooding problems on 4th Ave S by providing the required downstream drainage capacity. The project begins at the existing manhole at the southwest corner of the intersection of 3rd Ave S and Dayton. This manhole may need to be upsized depending on its diameter the minimum spacing between pipe knockouts. The project terminus point would be a new catch basin at the southwest corner of the intersection of 5th Ave S and Dayton St. This catch basin should be designed with knockouts for future pipe connections for Project 2. Traffic impacts for this project are expected to be moderate. Note that as the City moves towards implementation, survey base mapping and utility locating will be needed. In addition, because the modeling analysis relied on GIS data, supplemental modeling could be needed should there be any significant discrepancies between the GIS information and what will be surveyed. Some alignment changes may be necessary to avoid utility conflicts. It is recommended that when the final alignment and pipe depths are designed, the conveyance capacity and level of protection be checked. Alternative 3 Project 1 is shown on Figure 2-11 on the following page.

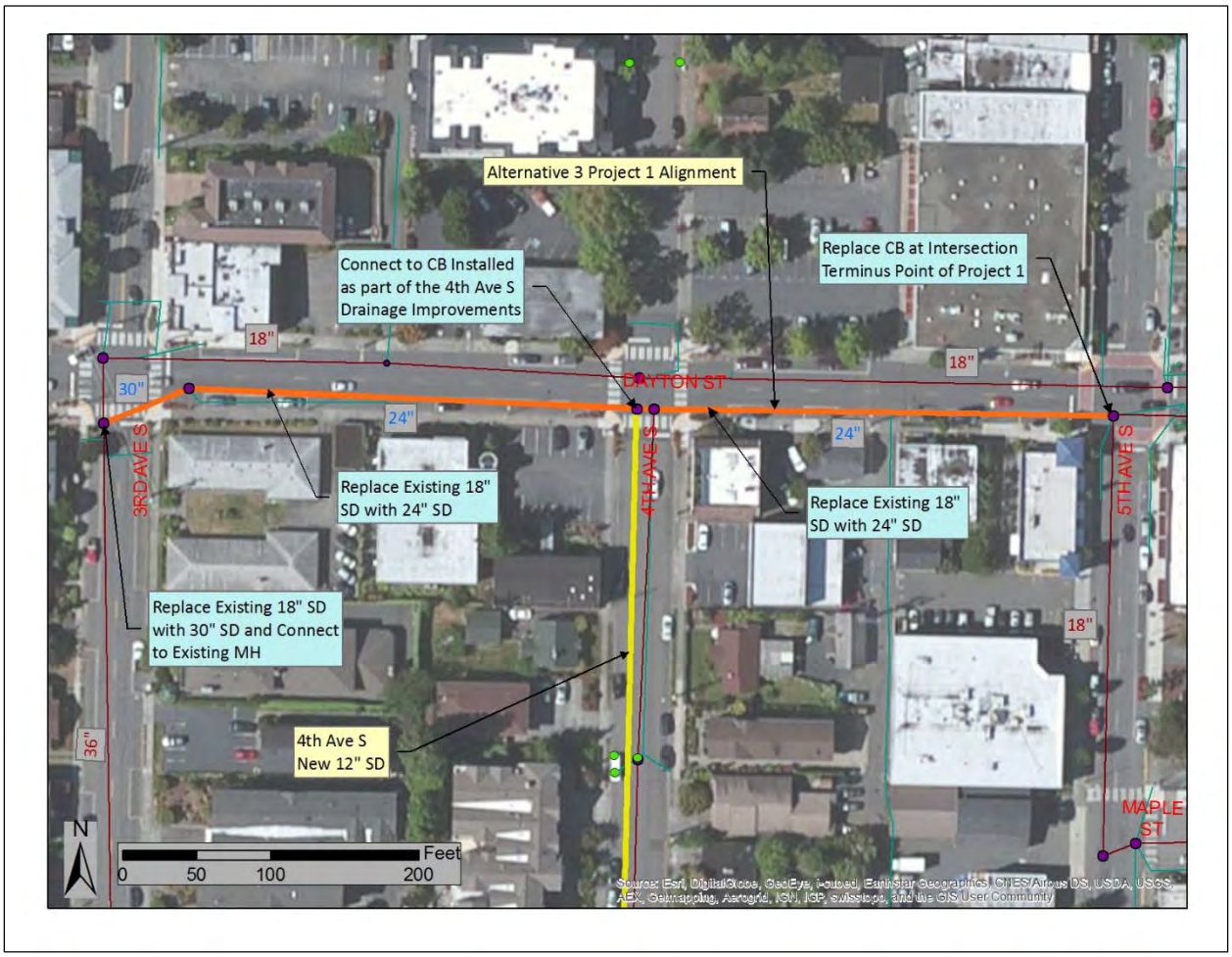


Figure 2-11: Alternative 3 Project 1

*Alternative 3 Project 2*

This project consists of installing approximately 660 LF of 24-inch storm drain on the south side of Dayton St between 5th Ave S and 6th Ave S, as well as a 12-inch pipe connection to the drainage system on the north side of Dayton St at the intersection with 6th Ave S (this would be the terminus point of Project 2). The new 24-inch pipe would constitute a parallel system on Dayton St in a segment where there are no existing storm pipes. These improvements would require a minimum of three new type 2 catch basins. It is possible that additional catch basins may be necessary to pick up lateral connections of Alternative 3 Projects 3 and 4. The catch basins installed on 6th Ave S would have knockouts for the future upsized pipe connections. Traffic impacts for this project are expected to be moderate because it traverses a commercial area and a busy intersection. Provisions will also be needed to maintain access to private properties along the alignment.

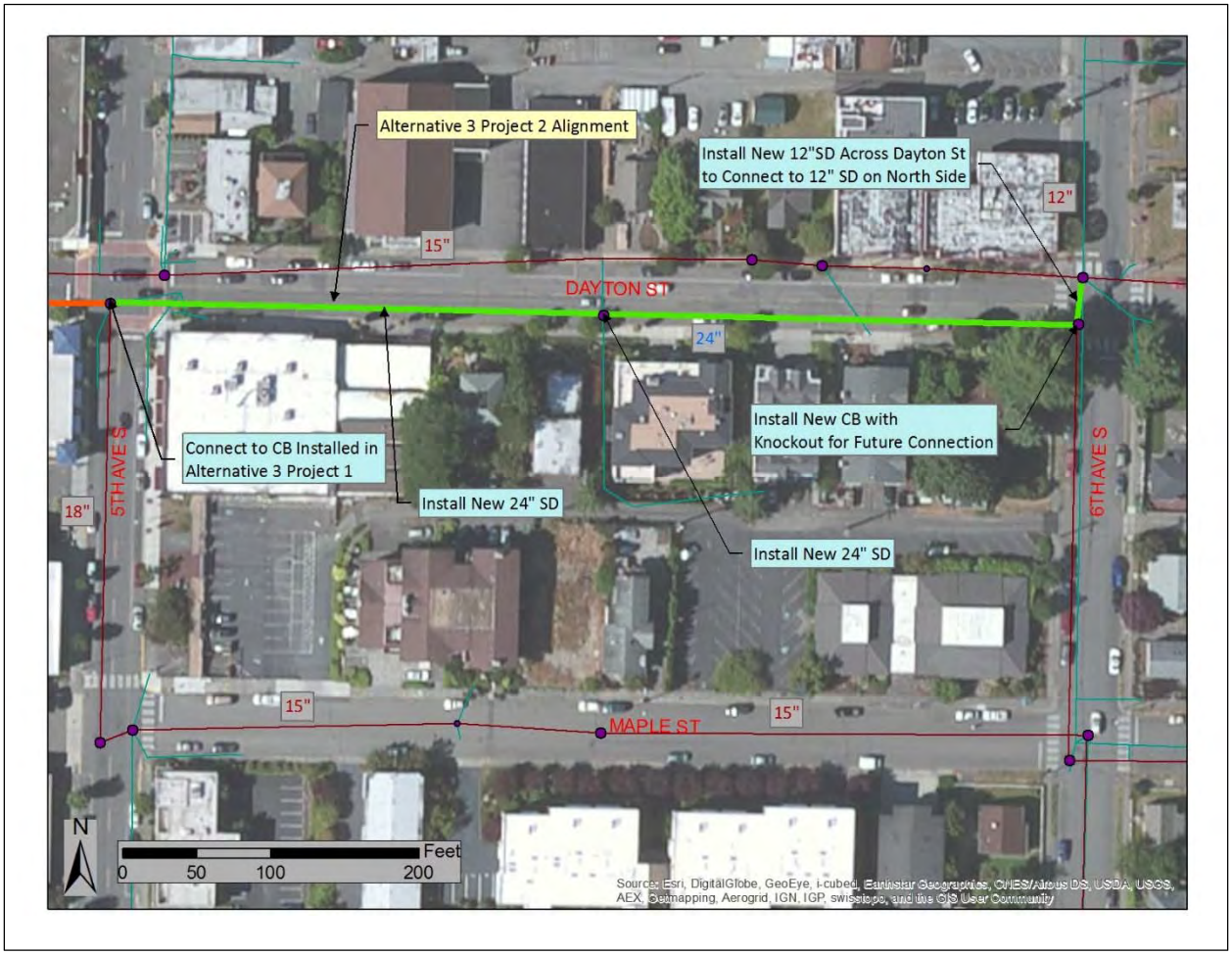


Figure 2-12: Alternative 3 Project 2

Similar to Alternative 3 Project 1, survey base mapping and utility locating will be needed. In addition, supplemental modeling could be needed should there be any significant discrepancies between the GIS information and what will be surveyed. Some alignment changes may be necessary to avoid utility conflicts. It is recommended that when the final alignment and pipe depths are designed, the conveyance capacity and level of protection be checked. Alternative 3 Project 2 is shown on Figure 2-12 above.

*Alternative 3 Project 3*

This project consists of replacing approximately 1350 LF of existing 8-inch with new 12-inch storm drains on the north side of Dayton St from 6th Ave S to 8th Ave S. These improvements would require approximately eight new Type 2 catch basins (Type 1 cannot be used to the depth of the pipe). Alternative 3 Project 3 is shown on Figure 2- 13 below:


Figure 2-13: Alternative 3 Project 3

This project would connect to the improvements in Project 2 at 6th Ave S where stormwater flows would have two outlets: the existing 12-inch pipe on the north side of Dayton St and the new 12-inch pipe across Dayton St. Project 3 would alleviate flooding in Problem Area 5 on Dayton St. Project 3 presents an opportunity to construct two of the subbasin-wide proposed inlet improvements. These two inlets are on the south side of Dayton St where there are currently no inlets. Traffic impacts for this project are expected to be moderate and provisions to maintain access to private properties will be needed. Similar to Alternative 3 Projects 1 and 2, survey base mapping, utility locating and possibly additional modeling will be needed during the design and implementation phase.

*Alternative 3 Project 4*

This project consists of installing approximately 1000 LF of new 18-inch and 24-inch storm drain. Specifically, it includes replacing the existing 12-inch pipe on 6th Ave S between Maple St and Dayton with a 24-inch pipe; and replacing the existing 15-inch and 8-inch pipes on Maple St between 6th Ave S and 7th Ave S with 24-inch and 18-inch pipes, respectively. These improvements would require a minimum of four new Type 2 catch basins. It is possible that additional catch basins may be necessary to pick up lateral connections. This project would connect to the improvements in Alternative 3 Project 2 at the catch installed at the southwest corner of the intersection of 6th Ave S and Dayton St. Project 4 presents an opportunity to construct one of the subbasin-wide proposed inlet improvements along Maple St. This project would ultimately alleviate flooding in problem areas 3 and 4 on 5th Ave S since it would divert a large portion of stormwater flows to the new 24-inch storm drain on Dayton St. Traffic impact for this project are expected to be moderate since it affects three intersections. Provisions to maintain access to private properties will be needed as well. Similar to the other Alternative 3 projects, survey base mapping and utility locating and possibly additional modeling will be needed during the design and implementation stage. Some alignment changes may be necessary to avoid utility conflicts. It is recommended that when the final alignment and pipe depths are designed, the conveyance capacity and level of protection be checked. Project 4 is shown on Figure 14 on next page.

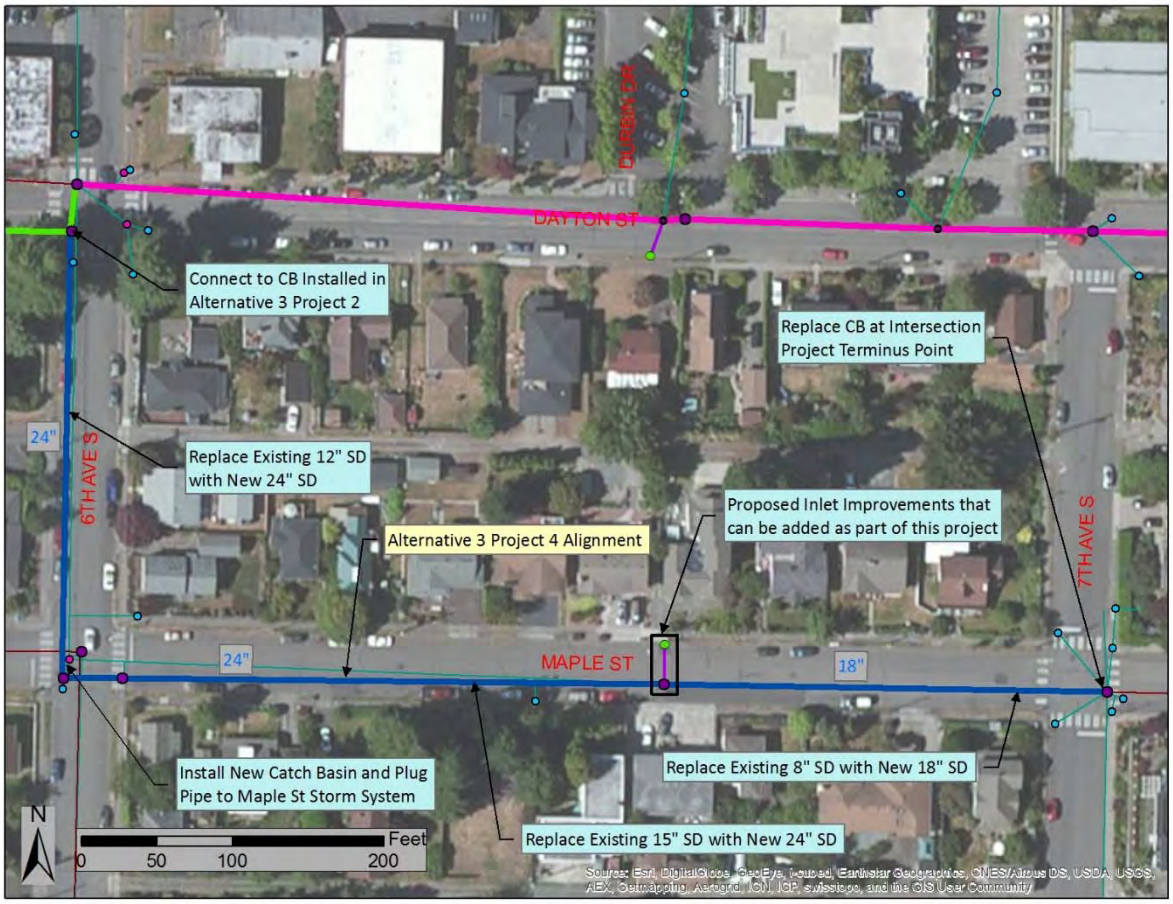


Figure 2-14: Alternative 3 Project 4

# Section 3
# Expanded Subbasin Study

## 3.1 Introduction

Section 3 includes a summary of the new expanded subbasin study work completed to evaluate the portion of the drainage conveyance system that was not previously evaluated in the primary system evaluation described in Section 2. Again, this information will be useful to the City in order to prioritize system replacements which would typically proceed in a "block by block" fashion. The methods used in the new analysis are similar to the prior analysis except that the catchment areas were further refined and made smaller in order to provide stormwater flow inputs typically on a block by block basis.

The modeling focused on the drainage system within public streets and did not include systems in alleys or lateral inlets. The organization of this expanded subbasin study includes sections on hydrologic and hydraulic analysis, current conveyance system level service, identification of undersized pipe systems and need for pipe replacements, and a summary of recommendations. The summary of recommendations combines the prior recommendations from Section 2 with the expanded subbasin study so that all of the recommendations are conveniently in one report section. The Attachments added based on the expanded study (Attachments E and F) would supersede the Attachments referenced in Section 2 as described in the text below.

## 3.2 Hydrologic and Hydraulic Assessment

The prior hydrologic and hydraulic analysis was updated and expanded to cover the remaining portions of the drainage system within the North Shellabarger Subbasin. The methods used for the updated analysis are similar to the previous analysis that this described in Section 2.3 of this report. These methods and any exceptions from the prior analysis are summarized in the following paragraphs.

- An XPSWMM model was developed to simulate both the hydrology of the subbasin and hydraulics of the primary conveyance system.
- Data for the XPSWMM model was mostly obtained from the City's GIS maps (including catch basin rim elevations, pipe sizes, material types, and inverts). The GIS maps give measure downs from the catch basin rim to the pipe inverts, so that this vertical distance was used, along with surface elevations taken from a digital elevation model in GIS, to determine approximate pipe invert elevations.
- The existing system was used in the updated modeling with one exception. This exception was that the "recommended system improvements" from the prior study (described in Section 2) was included in the updated model for existing conditions. The existing level of service for those existing pipe system modeled in the prior study was already presented in Figure 2-5. Because this portion of the system had

already been evaluated including recommended pipe replacements, it was more efficient for this current study to simply incorporate these results. Figure 3-1 presents the model schematic of the system modeled. Color coding is used to differentiate pipe segments added in this study from pipe segments modeled in the previous analysis. The combined pipe network shown on this figure constitutes the whole system modeled in SWMM. The node names shown correspond with the catch basin ID numbers assigned by the City's GIS maps and were used in the result tables.

In accordance with the scope of work, the system modeled focused on pipe systems within the City right-of-way. It did not include laterals (i.e., catch basins that conveyed runoff from one side of the street to the main storm line on the other). In one instance, a stream section outside of the City right-of-way was included in the model to maintain continuity of flows. This stream section is located within a block area bounded by 7th Avenue S, 8th Avenue S, Walnut Street, and Alder Street. The stream section was represented in the model by a theoretical open channel and was not modeled with implicit elevations or dimensions.

- Figure 3-2 presents the updated subbasin boundary map. As noted above, the subbasin was divided into much smaller catchments so that flow input data is more refined at roughly a block to block basis. Hydrologic input parameters, including catchment area, percent impervious, SCS curve number, and time of concentration were updated using the prior methodology (described in Section 2). The updated information is included in Attachment E. More specifically, Attachment E-1 supersedes Attachment A-2, and Attachment E-2 supersedes Attachment A-3. Figure 3-1 also shows those SWMM model nodes where the subbasin flows are input into the pipe system (i.e., inflow nodes). The updated delineation resulted in some refinements to the previous analysis along the outer boundary of the subbasin, such that approximately 3 acres was added to the overall subbasin area.
- One change from the prior modeling assessment was an investigation into whether the North Shellabarger Subbasin could receive overflows from the drainage basin to the East, near the intersection of Main Street and 9th Avenue S. The drainage system to the east is the 9th Avenue S drainage system which is part of the Shell Creek Basin. Figure 3-3 shows the tributary catchment area for the 9th Avenue S system (to Main Street), at which point it continues north beyond the north limits of the Shellabarger Subbasin. The 9th Avenue S system at Main Street includes a 15-inch diameter pipe system. Staff from Louis Berger visited this intersection to assess the possibility of overflows from the 9th Avenue S system to the Shellabarger Subbasin system. Field survey equipment was used to determine relative elevations and pipe slopes of the pipe 8-inch system extending west along Main Street and the 15-inch diameter system extending north. It was confirmed that the 8-inch diameter pipe system along Main Street does extend from 8$^{th}$ Avenue S to the 15-inch diameter pipe on 9$^{th}$ Avenue S. However, there is a high point in the system at a catch basin about 120 feet west of the 9$^{th}$ Avenue S. As such, under low flow conditions, a short length of Main Street would drain east to 9$^{th}$ Avenue S. However, during high flows there is the potential for a reverse flow situation if the 9$^{th}$ Avenue S system becomes surcharged.

To assess this possibility, a portion of the 9th Avenue S drainage system was included in the SWMM model (see Figure 3-1). In addition, an additional subbasin was created to model flows from the tributary area to the 9th Avenue S system. This subbasin is approximately 71.5 acres and is shown on Figure 3-3. The result was that during the 25-year event, the 15-inch pipe system becomes surcharged resulting in reverse flow in the 8-inch diameter pipe and a peak flow rate of 1.16 cfs was simulated to overflow into the North Shellabarger Subbasin. During the 50-year storm, a peak overflow rate of 1.5 cfs was simulated to reverse flow into the North Shellabarger Subbasin.

For this analysis, it was assumed that this potential flow reversal for extreme events will continue into the future. This amount of flow is relatively a small portion of the overall Shellabarger Subbasin. So if, in the future, the City improves the 9th Avenue South system, this flow would add a slight element of conservatism to the analysis.

- Base Flows added to the SWMM were revised as shown in Table 3-1. This was done because the modeled system was expanded and the base flows could be added to nodes further upstream in the system. Using the flows estimated in Table 2-2, the Dayton Street base flow was split across two nodes while the Maple Street base flow was split across four nodes.

Table 3-1:
Added Base Flows

| Location | Model Node | Base Flow Added (cfs) |
|---|---|---|
| 8th Ave S and Dayton St | 8-774 | 0.26 |
| 8th Ave S and Maple St | 8-743 | 0.26 |
| 8th Ave S and Walnut St | 8-701 | 0.26 |
| 7th Ave S and Dayton St | 8-778 | 0.26 |
| 7th Ave S and Maple St | 8-747 | 0.26 |
| 7th Ave S and Alder St | 8-712 | 0.26 |
| 6th Ave S and Dayton St | 8-790 | 0.26 |
| 6th Ave S and Maple St | 8-758 | 0.26 |
| 6th Ave S and Alder St | 8-717 | 0.26 |

- As with the prior analysis, simulated storm events included the 2-, 10-, 25-, 50- , and 100-year 24-hour Type 1A storm events were used (precipitations totals from NOAA isopluvial maps are in Attachment A-1).
- Following the initial modeling runs at the 100-year event, overflow paths (links in model parlance) between catch basins (model nodes) were added to the model. The overflow links were generically added and represented by a typical curb/gutter cross section (12-foot lane, cross slope of 2 percent and a 6-inch high curb).

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**Legend**

- SWMM Nodes
- Inflow Points
- SWMM Links (Phase 1)
- SWMM Links (Added in Phase 2)
- Storm Pipes Not Modeled

N

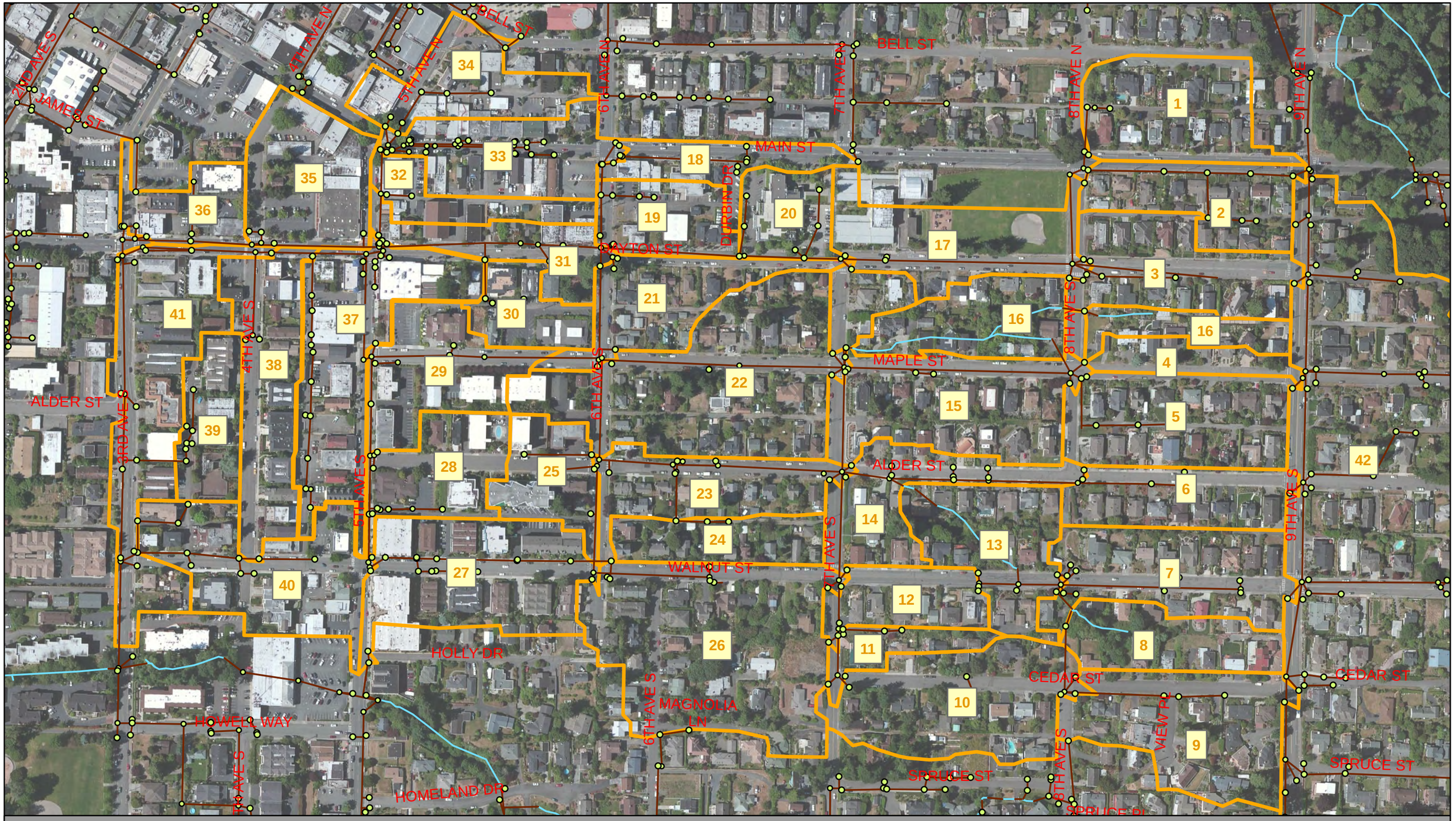
1 inch = 225 feet

0 125 250 500 Feet

Figure 3-1
System Modeled

Louis Berger

Back of Figure 3.1


BELL ST
MAIN ST
DURBIN DR
DAYTON ST
MAPLE ST
ALDER ST
WALNUT ST
HOLLY DR
HOWELL WAY
HOMELAND DR
MAGNOLIA LN
CEDAR ST
SPRUCE ST
SPRUCE PL
VIEW PL
2ND AVE S
JAMES ST
3RD AVE S
4TH AVE N
4TH AVE S
5TH AVE N
5TH AVE S
6TH AVE N
6TH AVE S
7TH AVE N
7TH AVE S
8TH AVE N
8TH AVE S
9TH AVE N
9TH AVE S
1
2
3
4
5
6
7
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9
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11
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14
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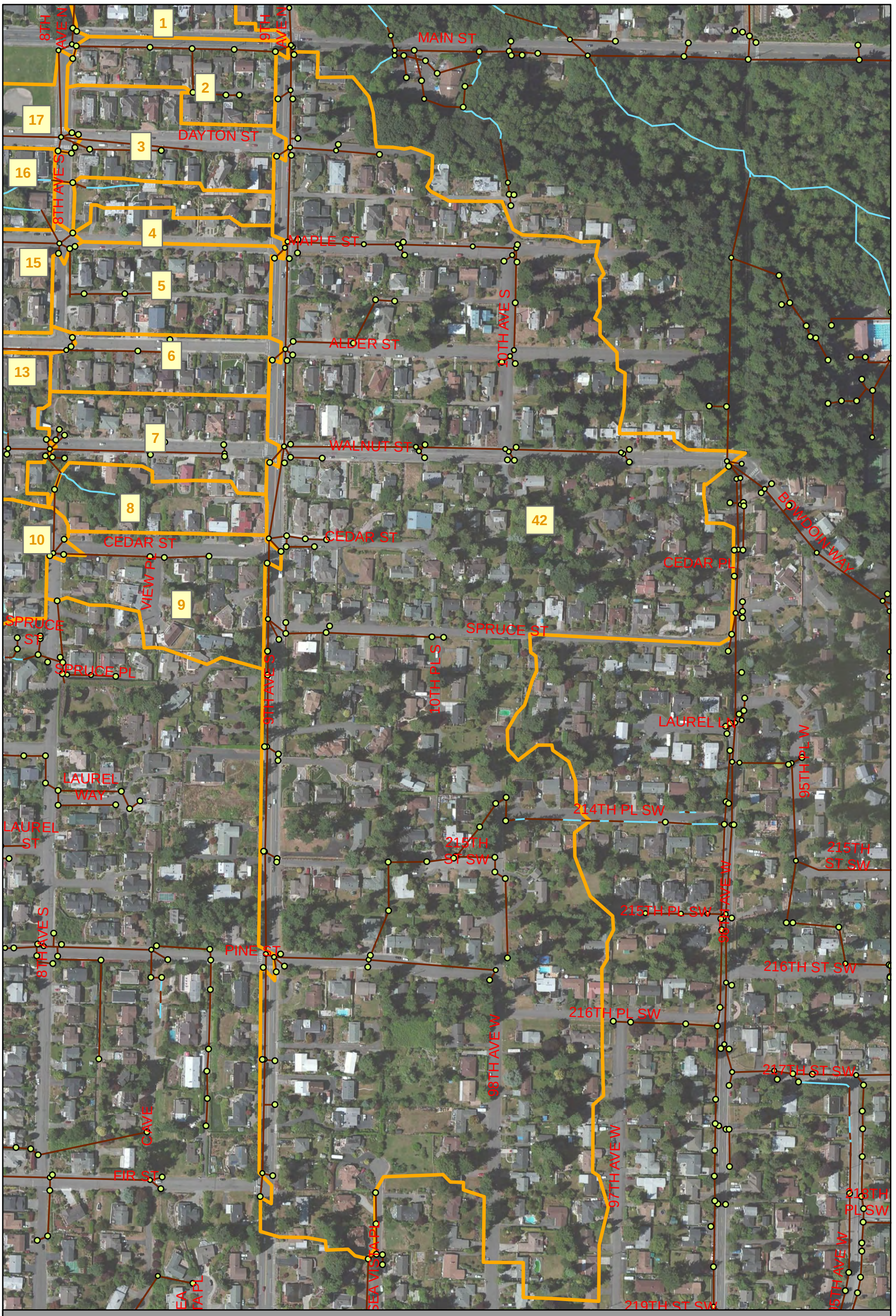
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
N
1 inch = 250 feet
Feet
0
125
250
500
Legend
Storm Catch Basin
Storm Pipe
Sub-Catchments
Figure 3-2
Subcatchments
Louis Berger

Back of Figure 3-2


8TH AVE S
9TH AVE N
MAIN ST
DAYTON ST
8TH AVE S
MAPLE ST
10TH AVE S
ALDER ST
WALNUT ST
CEDAR ST
CEDAR ST
CEDAR PL
BOWDOIN WAY
VIEW PL
SPRUCE ST
SPRUCE PL
SPRUCE ST
9TH AVE S
10TH PLS
LAUREL LN
9TH PL W
LAUREL WAY
LAUREL ST
214TH PL SW
215TH ST SW
215TH ST SW
215TH PL SW
9TH AVE W
8TH AVE S
PINE ST
216TH ST SW
216TH PL SW
98TH AVE W
217TH ST SW
CAVE
FIR ST
97TH AVE W
218TH PL SW
SEA VISTA PL
15TH AVE W
219TH ST SW
1
2
3
4
5
6
7
8
9
10
13
15
16
17
42
N
1 inch = 250 feet
0
125
250
500
Feet
Legend
Storm Catch Basin
Storm Pipe
Sub-Catchments
Figure 3-3
9th Ave S Subbasin
Louis Berger

Back of Figure 3-3.

## 3.3 Current Conveyance System Performance and Level of Service Assessment

A graphical summary of the current conveyance system level of service is presented on Figure 3-4. This information reflects a combination of modeling results of the prior modeling analysis of the primary drainage system (see Figure 2-5) combined with the current modeling analysis of the previously "unmodeled" portions of the conveyance system. As noted previously, these results do account for a partial flow diversion (or overflow) from the 9th Avenue S pipe system at Main Street for the extreme events.

In general, much of the new system modeled was simulated to have capacity in excess of the 50-year storm event. Out of all the new pipe network added to the model only two new areas are shown to have less than the 50-year level of service. These include:

- On 7th Avenue S between Alder St and Maple St: An existing 8-inch pipe (Node 8712 to 8747) floods the street at the 2-year storm. This may be partly due to the fact that the pipe extending west to catch basin 8713 is plugged and as such all flows from multiple catchments south of Alder St are directed north to Maple St.
- On 8th Avenue S between Dayton St and Main St: Two 8-inch pipes (Node 8413 to 8412 and then to 8774) and two 6-inch pipes (8414 to 8413 and 8395 to 8414) flood at the 10-year storm. The 8-inch pipe from 8412 to 8774 has a rather flat slope which reduces its conveyance capacity.

## 3.4 Pipe Replacement Plan

As noted above, the results of the analysis indicate that most of the undersized pipes were identified in the previous analysis and that only two new areas were identified as being undersized.

With these new results, the model then was modified to include pipe system upgrades to provide a minimum 50-year level of service, much of which had been done in the prior study (described in Section 2). It is noted that the prior analysis discussed whether to provide a 25-year or a 50-year level of service, and concluded that a 50-year level of protection was the preferred option. This is because the analysis concluded that the improvements needed for a 25-year level of protection would also provide a 50-year level of protection. Thus, because there were only two new problem areas added to the analysis, it is recommended that the 50-year level of protection be adopted for the new system improvements as well.

Determining pipe replacement sizes was typically done by simply increasing the pipe size in the model and dropping the pipe invert to reflect a larger pipe replacement (i.e., matching crowns with the existing pipe system). One exception to this is the pipe replacement along 8th Avenue between Main Street and Dayton Street and along Dayton Street from 8th Avenue S west to 7th Avenue S. During initial assessment of the replacement plan for this section, it was determined that the existing pipe system along

8th Avenue S between Main Street and Dayton Street is very flat and that based upon the grades and peak flows in the system, it would require an 18-inch diameter pipe, which would then downsize to a 12-inch diameter pipe along Dayton Street. A better approach would be to deepen a portion of the replacement system along Dayton Street just west of 8th Avenue S, which would allow a greater pipe slope for the replacement system along 8th Avenue S. In this way, the replacement pipe system can be reduced to 12-inch diameter. The depth that the system would need to be lowered to at the intersection of Dayton St and 8th Avenue S is 7 feet below grade surface.


## Pipe Level of Service Legend

< 2 Year
< 10 Year
< 25 Year
<50 Year
< 100 Year
>100 Year

## Legend (Other items)

- Catch Basin / Manhole
- Storm Pipe or Channel (Not Modeled in SWMM)

N

1 inch = 225 feet

0 112.5 225 450 Feet

Figure 3-4
Basinwide Existing Level of Service

Louis Berger

Back of Figure 3-4.

Upon upsizing the pipes whose level of service is less than that needed for a 50-year storm, the primary system modeled in the previous study was rechecked to determine if the increased pipe sizes upstream in the subbasin, (and subsequently the increased flows) do not require any further modifications. For example, for the 50-year storm, the flow at the subbasin outlet in SWMM increased from 60.4 cfs to 64 cfs, and the flow in the proposed 24-inch pipe on Dayton between 6th Ave S and 5th Ave S increased from 29.1 to 31.7 cfs. Some of the reasons for the increase in peak flow are:

- Improved pipe conveyance upstream of the previously modeled system
- The increase in overall subbasin area upon further site delineations
- The overflows from 9th Avenue S which peak at 1.5 cfs during the 50-year storm.

The review of the capacity of the previously modeled system revealed that the existing 18-inch pipes located on the south side of Dayton St between 4th Ave S and 3rd Ave S, need to be upsized to 30 inches (node 738 to 743) and 36 inches (node 743 to 742) instead of the previously determined sizes of 24 inches and 30 inches, respectively. These changes are needed because the previously sized upgrades resulted in no freeboard at the catch basin at the intersection of Dayton St and 5th Ave S.

The updated recommended plan for storm improvements with the North Shellabarger subbasin is shown on Figure 3-5. One additional modification to the recommended plan was the improvements at the intersection of 6th Avenue S and Maple St. The previous analysis assumed that there would be some catchment area (previously subbasin 5) draining to the existing system on Maple St and 5th Ave S. Because this study further broke down the subbasins and included the pipe system along 6th Avenue S, it required a more detailed analysis of how to distribute the flows and use the capacity of the Maple St drainage system without causing any flooding on Maple St. The improvements shown on Figure 3-5 assume that the new 24-inch bypass pipe on 6th Avenue S would be the primary conveyance pathway for flows from the catchments draining to Maple St and 6th Ave. As such, a catch basin would be needed along 6th Ave S to divert flows (from catchments 23, 24 and 25) to the new bypass. The 15-inch pipe on Maple is used as an overflow pipe and is connected to the proposed pipe improvements through a pipe. The elevation of this pipe would have to be set at approximately 96 ft NAVD for a proper split in flows during the 50-year storm. These modifications are similar to the existing cross-connecting pipe at the intersection but would be added to allow for more control on how much flow is directed to Maple St.

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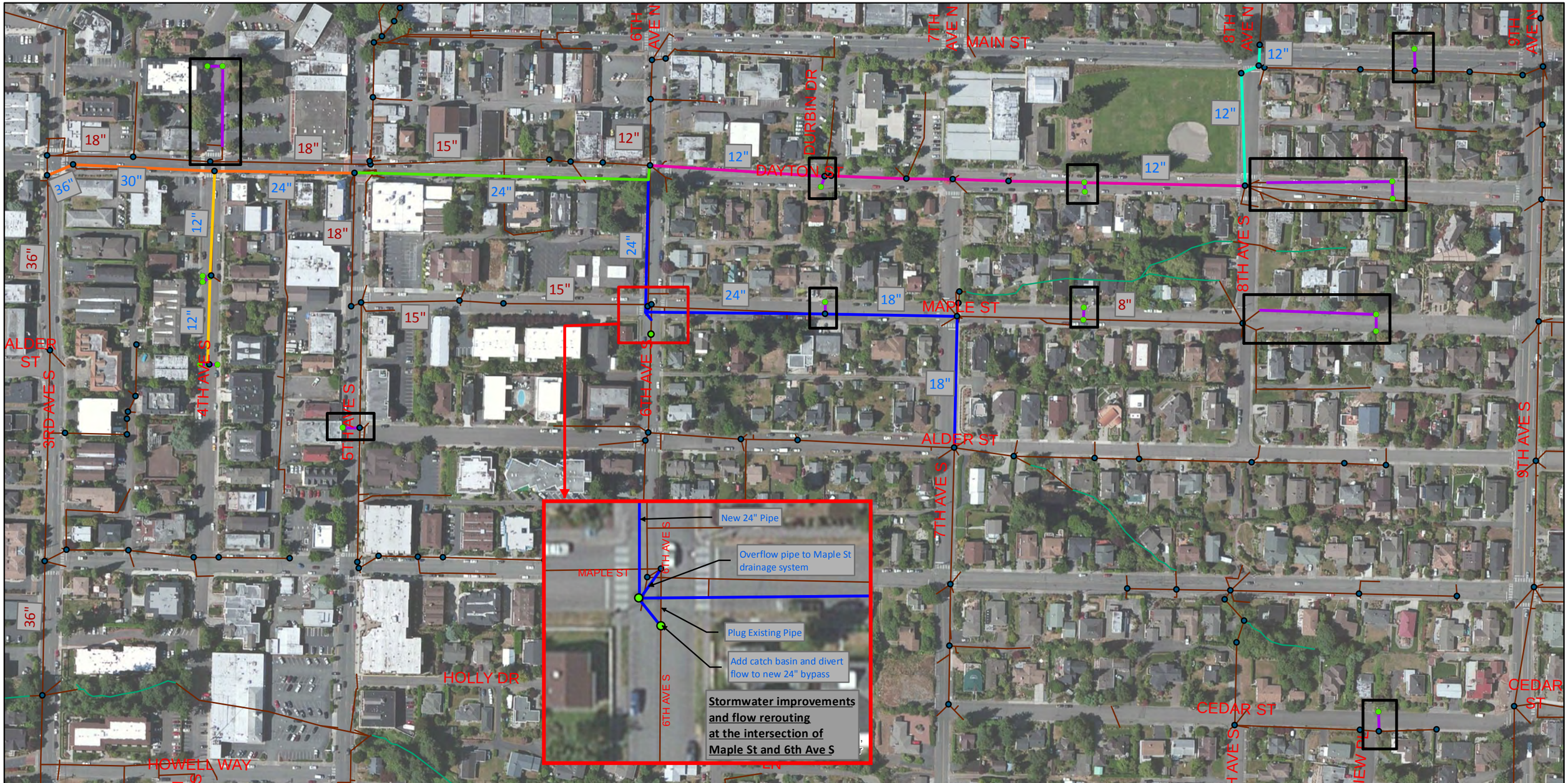


## Legend

- 4th Ave S Improvements - Completed in 2014
- Primary System Project 1 - Priority 2
- Primary System Project 2 - Priority 3
- Primary System Project 3 - Priority 4
- Primary System Project 4 - Priority 5
- Primary System Project 5 - Priority 6
- Catch Basins
- Proposed CB for Inlet Improvments
- Proposed Pipe for Inlet Improvements
- Existing Pipes with 50-year LOS
- Storm Ditch or Creek

N

1 inch = 210 feet

0 100 200 400 Feet

Figure 3-5
Recommended Plan

Louis Berger

Back of Figure 3-5.

## 3.5 Summary of Recommendations

The prior analysis evaluated three primary system alternatives, and Alternative 3 was recommended. Alternative 3 improvements were divided into four separate projects, each being one to two blocks of pipe replacements. Because the newly identified pipe replacement needed on 7th Ave are relatively short and connected to Alternative 3 project 4, it assumed that this improvement can be added to this project. It is also assumed that the pipe replacements needed on 8th Ave S were significant enough to be constructed as a single project. Hence a new Alternative 3 project 5 was added.

The following paragraphs constitute the revised descriptions of the Alternative 3 projects. They include the modifications introduced to Projects 1 and 4 and the addition of Project 5.

*Alternative 3 Project 1*

This project would now consist of replacing approximately 687 LF of 18-inch diameter storm drain with 312 LF of 24-inch diameter, 313 LF of 30-inch diameter storm drain, and 62-LF of 36-inch diameter storm drain on the south side of Dayton St between 3rd Ave S and 5th Ave S. These improvements would require a minimum of three new Type 2 catch basins. It is possible that additional catch basins may be necessary to pick up lateral connections. Note that the 60-inch diameter catch basin to be installed at the intersection of 4th Ave S and Dayton St as part of the 4th Ave S drainage improvements was sized to accommodate the new 30-inch diameter pipe. As noted previously in Section 2, Project 1 would fully resolve the flooding problems on 4th Ave S by providing the required downstream drainage capacity. The project begins at the existing manhole at the southwest corner of the intersection of 3rd Ave S and Dayton. This manhole may need to be upsized depending on its diameter the minimum spacing between pipe knockouts. The project terminus point would be a new catch basin at the southwest corner of the intersection of 5th Ave S and Dayton St. This catch basin should be designed with knockouts for future pipe connections for Project 2. Traffic impacts for this project are expected to be moderate. Note that as the City moves towards implementation, survey base mapping and utility locating will be needed. In addition, because the modeling analysis relied on GIS data, supplemental modeling could be needed should there be any significant discrepancies between the GIS information and what will be surveyed. Some alignment changes may be necessary to avoid utility conflicts. It is recommended that when the final alignment and pipe depths are designed, the conveyance capacity and level of protection be checked. Alternative 3 Project 1 is shown on Figure 3-6.

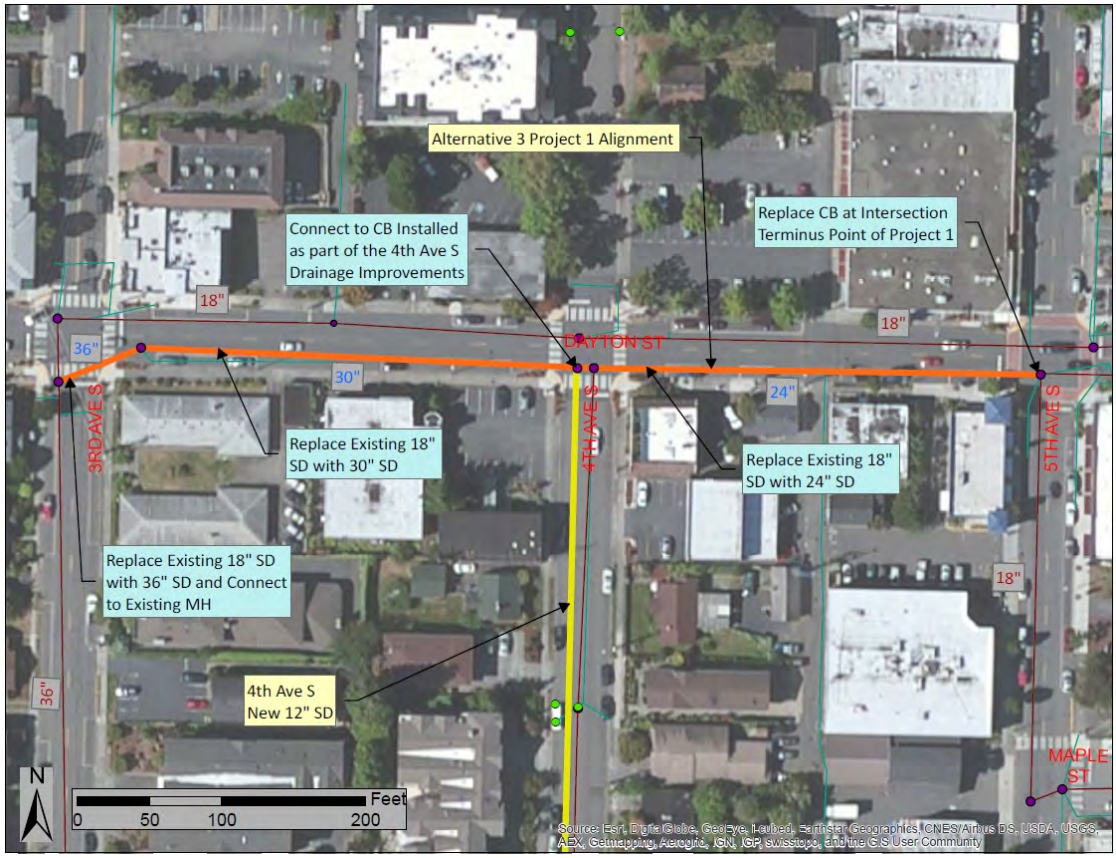


Figure 3-6: Alternative 3 Project 1 (Updates Figure 2-11)

*Alternative 3 Project 2*

This project consists of installing approximately 660 LF of 24-inch storm drain on the south side of Dayton St between 5th Ave S and 6th Ave S, as well as a 12-inch pipe connection to the drainage system on the north side of Dayton St at the intersection with 6th Ave S (this would be the terminus point of Project 2). The new 24-inch pipe would constitute a parallel system on Dayton St in a segment where there are no existing storm pipes. These improvements would require a minimum of three new type 2 catch basins. It is possible that additional catch basins may be necessary to pick up lateral connections of Alternative 3 Projects 3 and 4. The catch basins installed on 6th Ave S would have knockouts for the future upsized pipe connections. Traffic impacts for this project are expected to be moderate because it traverses a commercial area and a busy intersection. Provisions will also be needed to maintain access to private properties along the alignment. Alternative 3 Project 2 is shown on Figure 3-7.


Figure 3-7: Alternative 3 Project 2

(Same as Figure 2-12 of this report)

*Alternative 3 Project 3*

This project consists of replacing approximately 1350 LF of existing 8-inch with new 12-inch storm drains on the north side of Dayton St from 6th Ave S to 8th Ave S. These improvements would require approximately eight new Type 2 catch basins (Type 1 cannot be used to the depth of the pipe). Alternative 3 Project 3 is shown on Figure 3-8 below. This project would connect to the improvements in Project 2 at 6th Ave S where stormwater flows would have two outlets: the existing 12-inch pipe on the north side of Dayton St and the new 12-inch pipe across Dayton St. It would also, in the future, connect to Alternative 3 Project 5 at the intersection of 8th Ave S and Dayton St, where the catch basin depth needed is approximately 7 ft. Project 3 would alleviate flooding in Problem Area 5 on Dayton St. Project 3 presents an opportunity to construct two of the subbasin-wide proposed inlet improvements. These two inlets are on the south side of Dayton St where there are currently no inlets. Traffic impacts for this project are expected to be moderate and provisions to maintain access to private properties will be needed. Similar to Alternative 3 Projects 1 and 2, survey base mapping, utility locating and possibly additional modeling will be needed during the design and implementation phase.

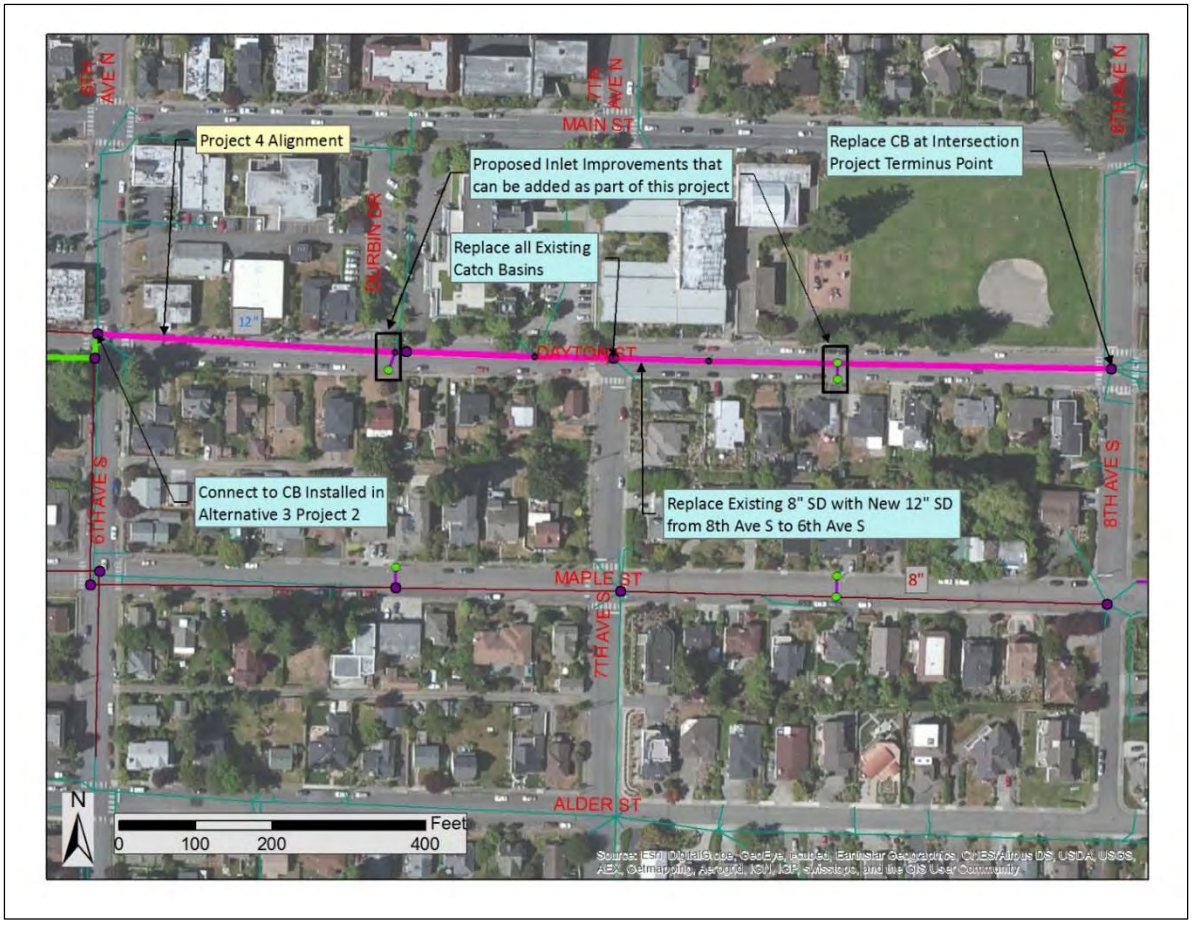


Figure 3-8: Alternative 3 Project 3

(Same as Figure 2-13 of this report)

*Alternative 3 Project 4*

This project consists of installing approximately 1320 LF of new 18-inch and 24-inch storm drain. Specifically, it includes replacing the existing 12-inch pipe on 6th Ave S between Maple St and Dayton with a 24-inch pipe; replacing the existing 15-inch and 8-inch pipes on Maple St between 6th Ave S and 7th Ave S with 24-inch and 18-inch pipes, respectively; and replacing the existing 8-inch pipe on 7th Ave S between Maple St and Alder St with an 18-inch pipe. These improvements would require a minimum of six new type 2 catch basins. It is possible that additional catch basins may be necessary to pick up lateral connections. A new 12" overflow pipe at approximately elevation 96 ft NAVD would be installed between the intersecting pipe systems at 6th Ave S and Maple St. This project would connect to the improvements in Alternative 3 Project 2 at the catch installed at the southwest corner of the intersection of 6th Ave S and Dayton St. Project 4 presents an opportunity to construct one of the subbasin-wide proposed inlet improvements along Maple St. This project would ultimately alleviate flooding in problem areas 3 and 4 on 5th Ave S since it would divert a large portion of stormwater flows to the new 24-inch storm drain on Dayton St. Traffic impact for this project are expected to be moderate since it affects four intersections. Provisions to maintain access to private properties will be needed as well. Similar to the other Alternative 3 projects, survey base mapping and utility locating and possibly additional modeling will be needed during the design and implementation stage. Some alignment changes may be necessary to avoid utility conflicts. It is recommended that when the final alignment and pipe depths are designed, the conveyance capacity and level of protection be checked. Project 4 is shown on Figure 3-9 on next page.

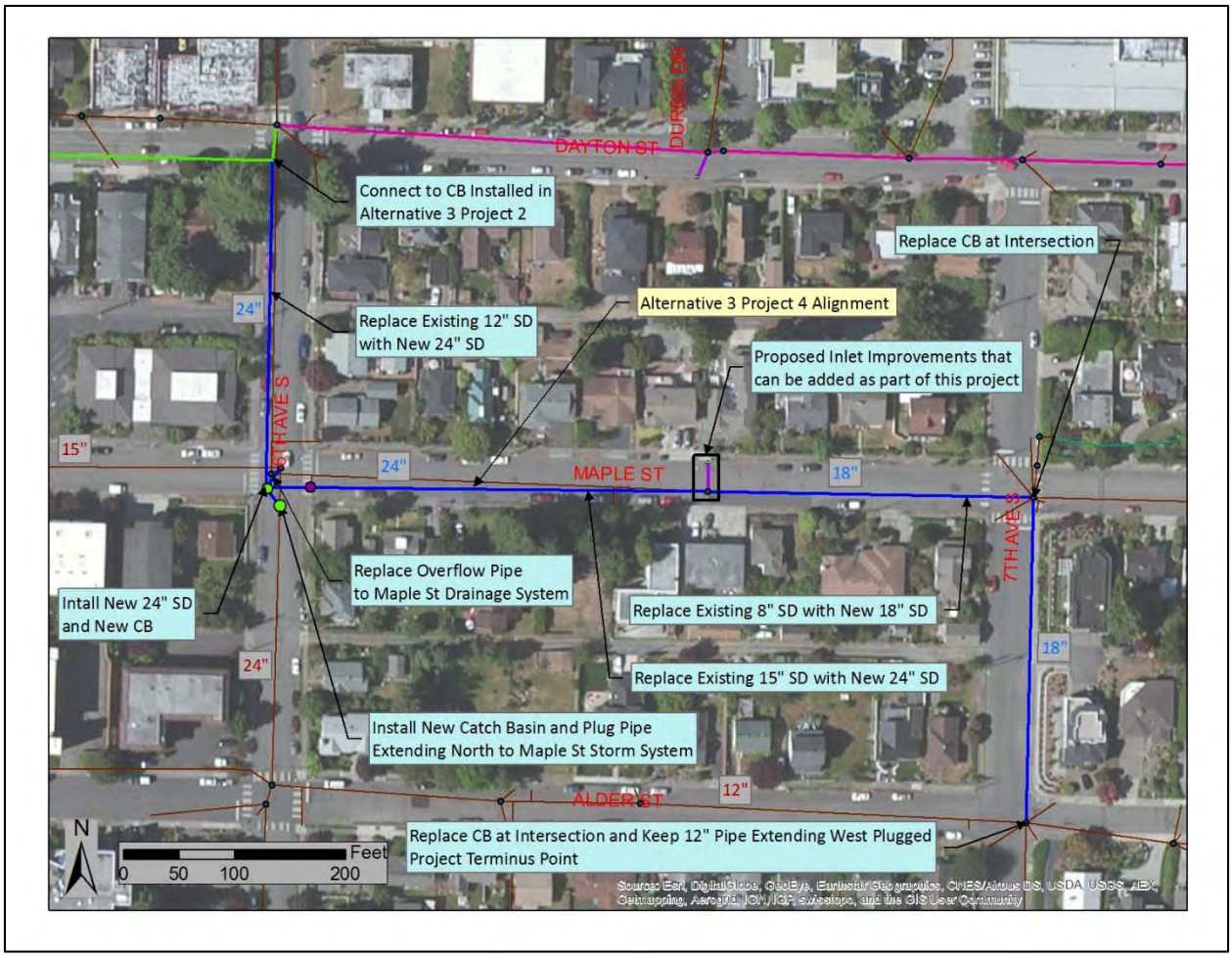


Figure 3-9: Revised Alternative 3 Project 4 (Replaces Figure 2-14)

### *Alternative 3 Project 5*

This project consists of installing approximately 350 LF of new 12-inch storm drain. Specifically, it includes replacing the existing 6-inch and 8-inch pipes on 8th Ave S between Dayton St and Main St with 12-inch pipes. These requirements would require three new type 1 catch basins. This project would connect to the improvements in Alternative 3 Project 3 at the intersection of 8th Ave S and Dayton St. This project would alleviate flooding at the intersection of 8th Ave S and Main St. To increase the slope of this pipe system, it must get deeper as it extends south. The additional depth needed at the catch basin at this intersection would be a work item for Alternative 3 Project 3. Traffic impact for this project are expected to be low to moderate since it includes pipe segments crossing both 8th Ave S and Main St. Similar to the other Alternative 3 projects, survey base mapping and utility locating and possibly additional modeling will be needed during the design and implementation stage. Some alignment changes may be necessary to avoid utility conflicts. It is recommended that when the final alignment and pipe depths are designed, the conveyance capacity and level of protection be

checked. Project 5 may present an opportunity to construct inlet improvements on Dayton St and Main St upstream of the project area (also shown on Figure 3-5). This project is shown on Figure 3-10.

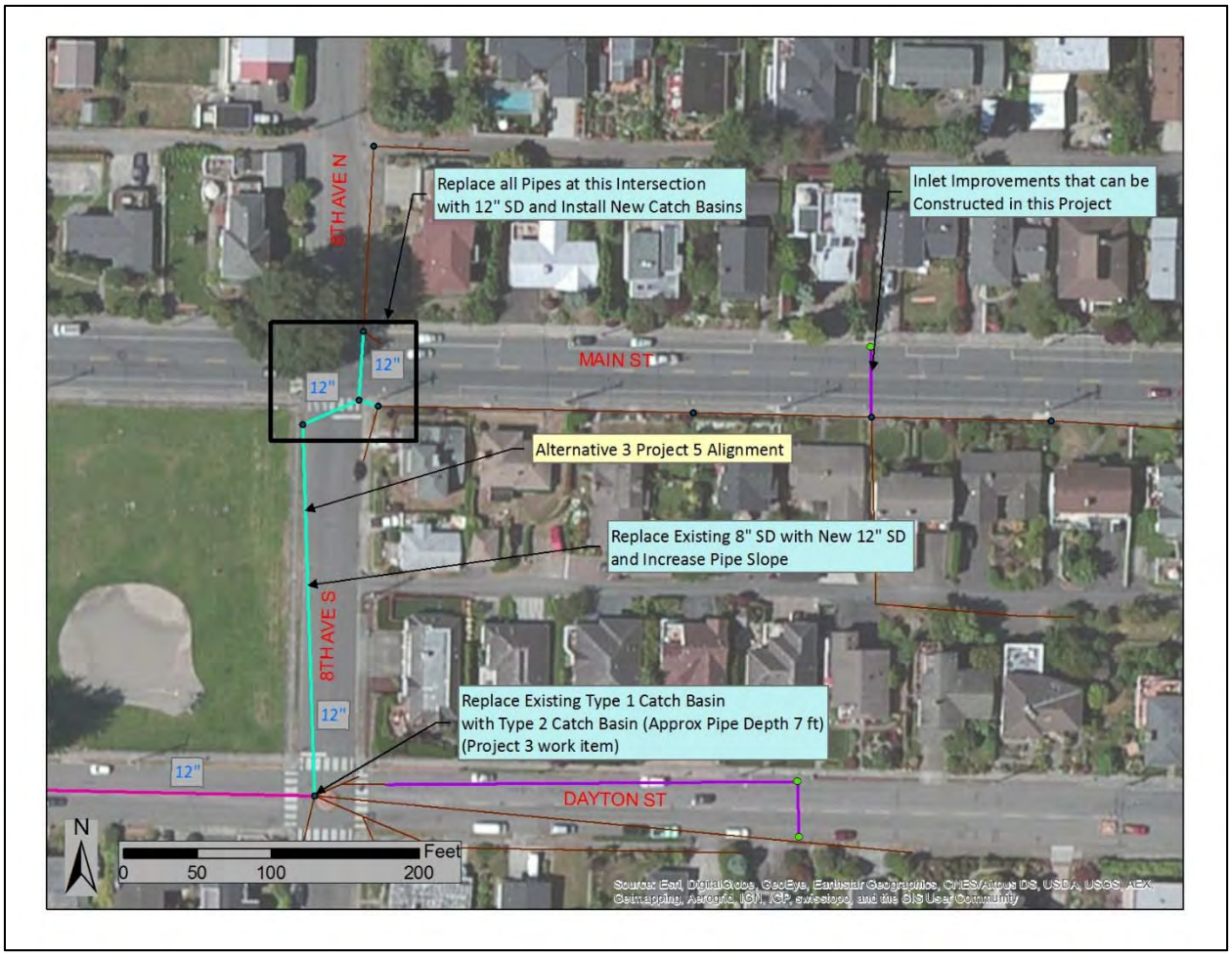


Figure 3-10: Alternative 3 Project 5

The revised cost estimates are included in Attachment F which supersedes Attachment D. They are also summarized below in Table 3-2.

Table 3-2:
Project Descriptions and Costs

| Priority | Project ID - Name | Description | Cost |
|---|---|---|---|
| 1 | Primary System (PS) Alt. 3 – Project 1 | Replace System along Dayton from 3rd Ave S to 5th Ave S | $483,000 |
| 2 | Primary System (PS) Alt. 3 – Project 2 | Construct Parallel System along Dayton from 5th Ave S to 6th Ave S | $372,000 |
| 3 | Primary System (PS) Alt. 3 – Project 3 | Replace System along Dayton from 6th Ave S to 8th Ave S | $649,000 |
| 4 | Primary System (PS) Alt. 3 – Project 4 | Replace System along 6th from Dayton to Maple an along Maple from 6th Ave S to 7th Ave S | $745,000 |
| 5 | Primary System (PS) Alt. 3 – Project 5 | Replace System along 8th Ave S from Main Street to Dayton Street | $200,000 |

Additionally, the 4th Ave S early action drainage improvements, as described in Section 2, have been constructed at the time of the completion of this report. Furthermore, the subbasin wide inlet improvements proposed in the previous report (and discussed below) are still considered an integral element of the recommended plan.

*Subbasin Wide Inlet Improvements – Program to Add Catch Basins/Inlets*

This alternative reflects more of a general system improvement rather than to address a specific problem area. It includes a program to add additional curb inlets along those portions of streets where the spacing between catch basins is large or spans the whole length of the block. It can be considered independent of the primary system alternatives and thus added to any of the above alternatives. The insufficient number of inlets was observed during the November 2013 site visit. One resident on Dayton St near 8th Ave S confirmed that the gutter flow at the end of the long block was so deep that it would overwhelm the catch basin at the end of the block and overflow the street to the west. No modeling was done to analyze this alternative. Rather, a mapping exercise was completed using the City's GIS maps showing the drainage system to identify long blocks where there appeared to be a lack of catch basins. A typical maximum design spacing for catch basins is 300 feet (less at flat grades). Using the maps, the locations of the additional catch basins were identified. In many cases, storm drain pipe extensions would be needed in order to connect the catch basins to the system (typically to a midblock location). Figure 3-5 shows the proposed additional inlets and pipes. The flood reduction benefits of these improvements were not quantified but it can be assumed that these inlets would help capture gutter flow and reduce the potential for excessive water ponding at intersections.

In summary, the pipe system improvements include the following:

- 22 Catch Basins (Type 1)
- Pipe System Improvements with 8-inch Diameter Pipe: 350 LF (assumed for laterals)
- Pipe System Replacement with 12-inch Diameter Pipe: 700 LF (assumed for non-laterals)

The cost estimate for these improvements is $572,000, although they will likely be spread out onto multiple projects.