CITY OF Salem AT YOUR SERVICE

MILL CREEK BASIN PLAN

September 2019

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MILL CREEK BASIN DESCRIPTION

General Overview

Mill Creek is the largest creek within the City of Salem. It originates in the foothills of the Cascade Mountain Range. The watershed varies in elevation from approximately 116 feet at its confluence with the Willamette River to approximately 2,200 feet along its eastern boundary. It has a mean watershed elevation of 530 feet and a drainage area of approximately 111 square miles. [Unless otherwise stated, all elevations mentioned in this document are in the National Geodetic Vertical Datum of 1929 (NGVD 29).]. Incorporated communities in the Mill Creek basin include: City of Stayton, City of Aumsville, City of Turner, and City of Salem. From its headwaters in the lower foothills of the Cascade Mountains, Mill Creek flows west through the Cities of Stayton and Aumsville to the City of Turner and then flows northwest through the City of Salem. Major tributaries to Mill Creek include Beaver Creek, McKinney Creek, and Battle Creek. Salem Ditch (also known as Stayton Ditch) diverts water from the Santiam River to Mill Creek. The diversion provides water for irrigation and augments low flow conditions in Mill Creek during the summer months.

Only the portions of Mill Creek Basin within the Salem city limits were studied in detail for this analysis. The upstream extent of the detailed study is located approximately 0.75 miles upstream of the Mill Creek Correctional Facility. The downstream extent of the detailed study area is the confluence with the Willamette River. The drainage area for the detailed study area is 8.3 square miles. It is located north of the Pringle Creek Basin and south of the East Bank, Upper Claggett Creek, and Little Pudding River basins. The majority of the detailed study area is developed residential, commercial, gravel mining, and industrial land use. A small portion of the southeast corner is undeveloped agriculture, forest, grassland, and pasture. Several large quarry ponds are located in the upstream portion of the detailed study area.

The City of Salem urban growth boundary (UGB) encompasses approximately 93% of the detailed study area. The minimum and maximum elevation within the study area are 120 feet and 650 feet, respectively. There are two major water diversions from Mill Creek within the City of Salem. The Shelton Ditch diversion, which is located approximately 1,500 feet downstream of Hawthorne Avenue, is a constructed channel that is used to reduce flood risk along Mill Creek. Shelton Ditch outfalls into Pringle Creek in Pringle Park. The Mill Race diversion, located approximately 300 feet downstream of 21st Street, is a constructed channel that is primarily used to divert water to the historic Thomas Kay Woolen Mill. The Mill Race outfalls into Pringle Creek downstream of Liberty Street SE. **Error! Reference source not found.** shows the limits of the Mill Creek Basin detailed study area, the entire extent of the Mill Creek Basin, and the Mill Creek drainage network.

The Mill Creek Basin detailed study area is relatively flat with a few hills along the southeastern boundary. The northeast portion is largely composed of McNary Field, developed industrial land use, and a few pockets of residential area. Downtown Salem, Willamette University, and the Oregon State Capital complex are located in the northwest portion of the study area. The central portion of the detailed study area is composed of commercial and government development, with significant amounts of impervious area. This includes the Oregon State Hospital, the Oregon State Penitentiary, and the ODOT Motor Pool. The southeast portion of the detailed study area includes several large quarry pond lakes, Corban University, industrial land use, and a few agricultural areas.

The low lying and relatively flat terrain adjacent to the streams makes much of the Mill Creek detailed study area flood prone. The relatively flat terrain that forms the eastern portion of Pringle Creek Basin and its close proximity to Mill Creek allows high flows in Mill Creek to overflow into the Pringle Creek Basin. Several privately-owned large quarry ponds located southeast of the Interstate 5 and Highway 22 interchange with a total area of approximately 200 acres are used to route and store high flows in Mill Creek. Additional detention facilities and wetlands with a total area of approximately 60 acres were constructed east of the quarry ponds as part of the Mill Creek Corporate Center development.

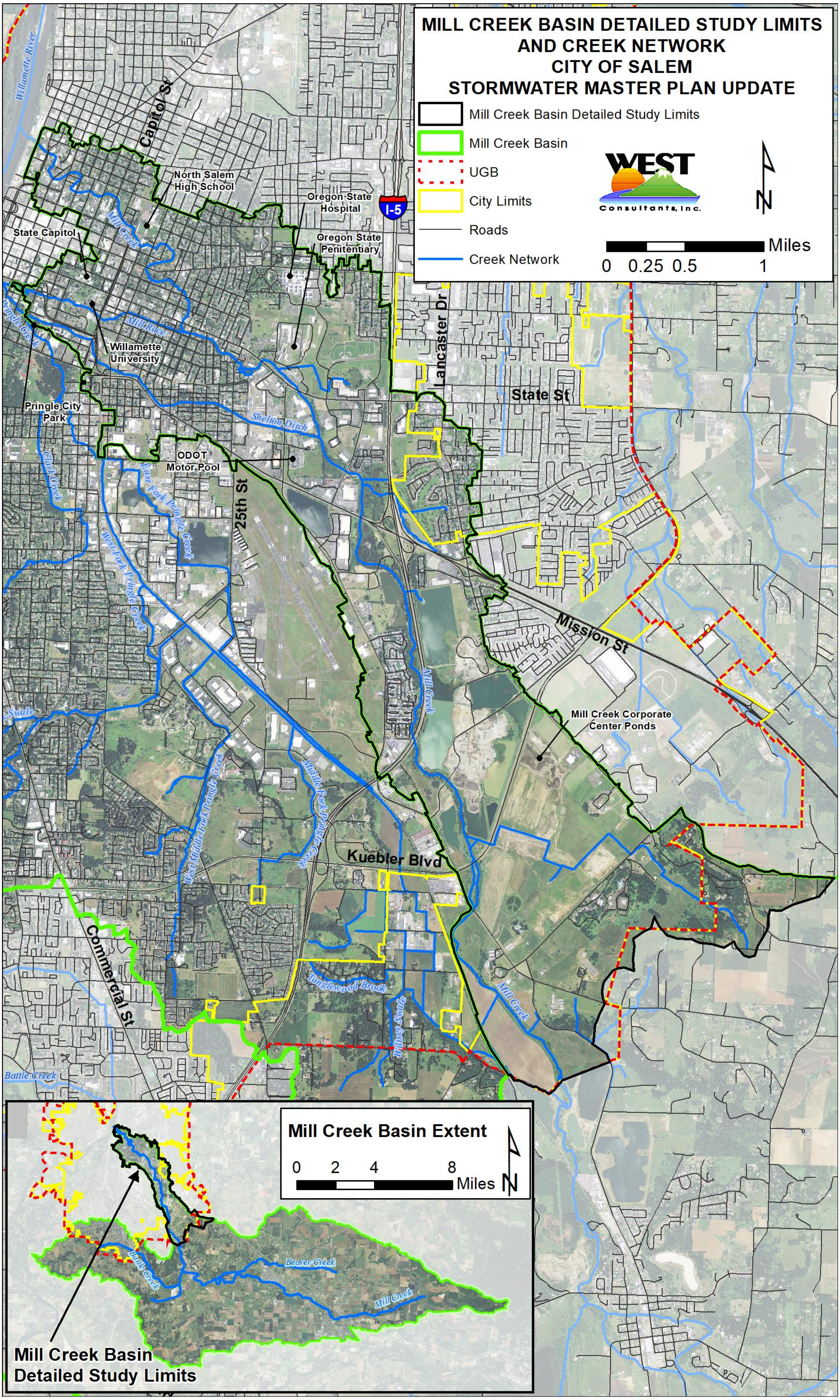


Figure 1 – Mill Creek Basin detailed study limit and channel network

Areas of Concern

There are several areas of concern within the Mill Creek Basin that have a history of flooding during large storm events. The most recent major storm events occurred in January 2012 and February 1996. Two minor storm events occurred in December 2015. During the January 2012 and December 2015 storm events, photos were taken by the City of Salem and/or WEST Consultants Inc. to document the observed flooding (see **Appendix 11.A**). Following the February 1996 storm event, the approximate observed flood extents were mapped by the City. The February 1996 flood inundation extents and the January 2012 and December 2015 observed flooding locations are shown in **Figure 2**.

Along Mill Creek, historic flooding was documented at North Salem High School during the 1996 and 2012 storm events. During both events, water overflowed the banks of Mill Creek upstream of 14th Street and inundated portions of North Salem High School. During the 1996 storm event, water overflowed the banks of Mill Creek near the Oregon State Penitentiary, and traveled northwest through residential areas until discharging back into Mill Creek at North Salem High School. Since the 1996 storm event, a berm has been constructed along the bank of Mill Creek near the penitentiary to prevent the flood water from routing though the residential area. While flooding was not observed at North Salem High School during the December 2015 storm events, city staff observed that the Mill Creek channel, adjacent to the high school, was near capacity.

Further upstream, flooding was observed near 17th Street in residential areas along Mill Creek during both the 2012 and 1996 storm events. Near the Mill Race diversion, significant flooding was observed at the businesses along State Street and in the residential area south of Mill Creek for both the 2012 and 1996 storm events. Water overflowed the banks of Mill Creek and flowed westward along the streets that parallel the Mill Race until flowing back into either Mill Race or Shelton Ditch. Minor flooding was observed along State Street for the December 2015 storm events. During the 1996 and 2012 storm events, water overflowed the left (south) bank of Mill Creek just upstream of the Shelton Ditch diversion. It flowed south through the ODOT motor pool and then into Shelton Ditch. Some minor flooding was observed near the motor pool during the 2015 storm events.

The water surface elevations along Mill Creek during the 1996, 2012, and both 2015 storm events were high enough to overtop the diversion weir located upstream of I-5 causing water to overflow into the quarry ponds. During the 1996 and 2012 storm event, the water surface elevations in Mill Creek were sufficiently high to cause water to overflow into the Pringle Creek Basin at multiple locations. The most significant overflow occurs at the I-5 at Turner Road overpass. From this location, Mill Creek floodwaters travel west through McNary Field and through developed residential and industrial areas north of McGilchrist Street and west of 25th Street. Eventually the floodwaters reach East Fork Pringle Creek, increasing the flood risk for the residential areas located north of Oxford Street. The overflowing water also increases the flood risk along Turner Road and the eastern portion of the airport. The map of the 1996 flood extents suggest that street flooding was also observed in residential areas along Shelton Ditch, upstream of Lee Street, and in the industrial areas located upstream of 25th Street. For both the 2012 and 1996 storm events, water overflowed the banks of Shelton Ditch upstream of 25th Street and inundated Pringle Parkway and adjacent buildings, eventually flowing back into Shelton Ditch.

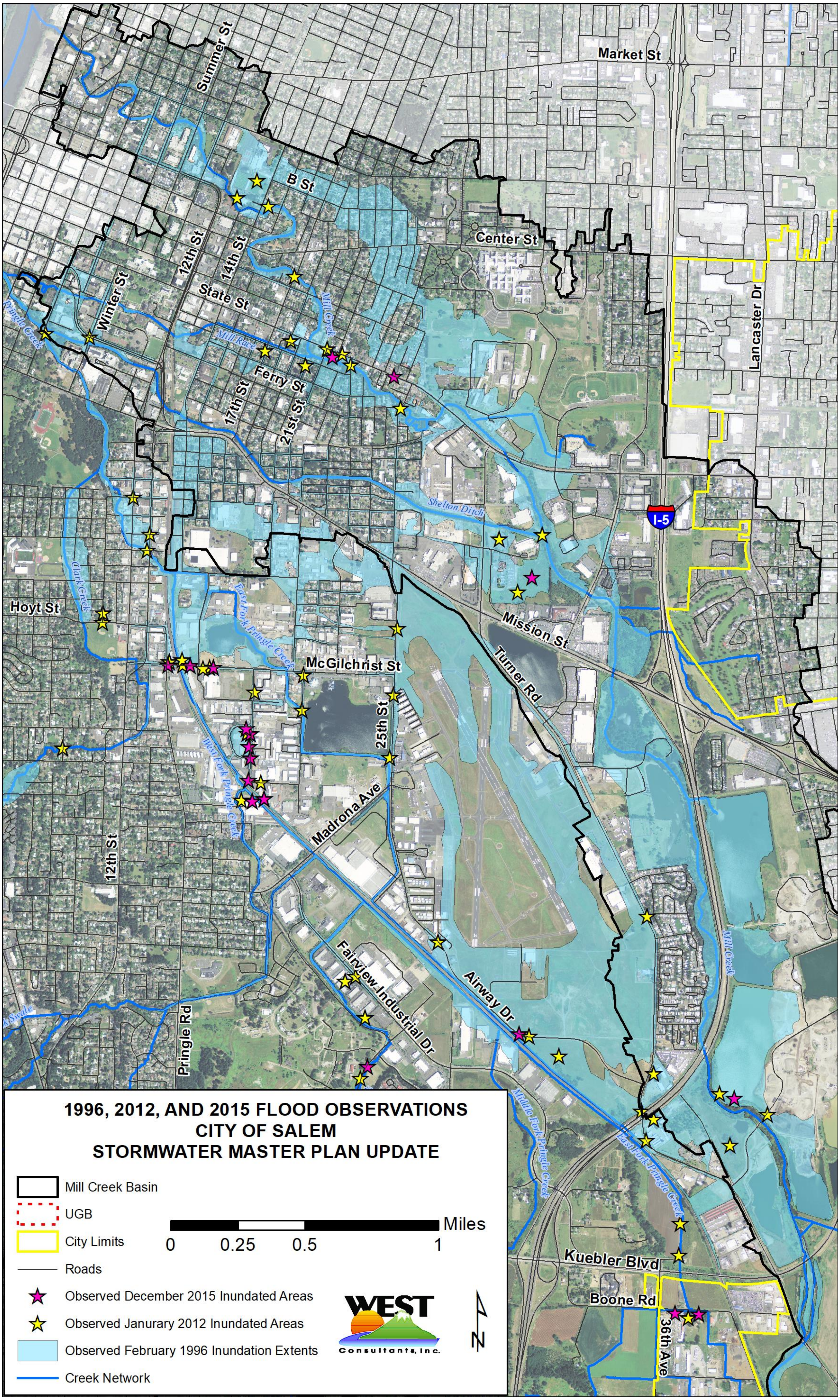


Figure 2 – Approximate 1996 flood inundation extents and observed January 2012 and December 2015 flooding locations

Findings of 2000 Stormwater Master Plan

In the Stormwater Master Plan (SWMP) and Drainage System Improvement Plan (DSIP) developed for the City of Salem by Montgomery Watson (2000), portions of the Mill Creek Basin were modeled using a planning-level xpswmm model, which provided coupled hydrologic and hydraulic modeling of the watershed and stormwater system. In that effort, the Mill Creek Basin was divided into 91 subbasins. The primary purpose of the model was to detect areas within the storm sewer network that were at-risk of surcharge during the 10-year 24-hour SCS Type-1A rainfall event. Models were developed for existing and full build-out conditions. The Mill Creek, Shelton Ditch, and Mill Race channels were not evaluated as part of the 2000 SWMP.

The findings of the 2000 DSIP included 39 recommended Capital Improvement Projects (CIPs) within the Mill Creek Basin. The recommendations included bridge/culvert replacements, channelization, vegetation modifications, and detention facility construction. The total cost for the recommended CIPs was $20,986,930 in 2000 dollars.

MILL CREEK BASIN MODEL

Model Selection Process

The 2000 SWMP xpswmm model was used to develop a planning-level model of Mill Creek Basin. However, the planning-level model lacks the detail needed to accurately model natural channels, hydraulic structures, complex 2-dimensional (2-D) flow, and overflow routing during high flow conditions. Since the Mill Creek Basin stormwater drainage system includes open channel conveyances (both natural channels and ditches), closed conduit stormwater systems (pipes and manholes), bridges and culverts, detention facilities, and complex two-dimensional flow conditions, XP Solutions' xpstorm with XP2D was selected as the most appropriate model. A detailed description of the model selection process is presented in **Appendix F** of the Stormwater Master Plan.

Model Development

The xpstorm model for the Mill Creek Basin is divided into two components, runoff and hydraulics. The runoff component simulates the hydrologic processes in the watershed, including precipitation, hydrologic abstractions, hydrologic routing, and watershed storage. The hydraulics component simulates the conveyance and storage for channels, floodplains, weirs, bridges, culverts, pipes, and detention facilities.

Runoff Component Development

The development of the runoff component of the xpswmm model included:

- Subbasin delineation
- Watershed characteristics pre-processing
- Rainfall data collection and processing
- Design storm development
- Developing design storm inflow hydrograph for Mill Creek using the Army Corps of Engineers Hydrologic Modeling System (HEC-HMS) version 4.1.

Each of these development steps is summarized in the following sections:

<u>Subbasin Delineations</u>

Since the development of the 2000 SWMP, high density topographic data for the Pringle Creek Basin has become available from the Oregon LiDAR Consortium (Watershed Concepts, 2009). This topographic data, along with current stormwater system information, land use data, and 2-ft contour mapping provided by the City of Salem were used to update and revise the subbasin boundaries from the 2000 SWMP. Subbasins were divided along topographic ridges according to the high-density LiDAR data and 2-ft contour mapping, while generally maintaining a minimum subbasin outlet pipe size of 15-24 inches. Subbasins were also delineated based on the locations of recognized flood water storage areas, stream confluences, clear distinctions in land use, and major bridges and culverts.

A total of one hundred eight (108) subbasins were defined within the Mill Creek Basin.

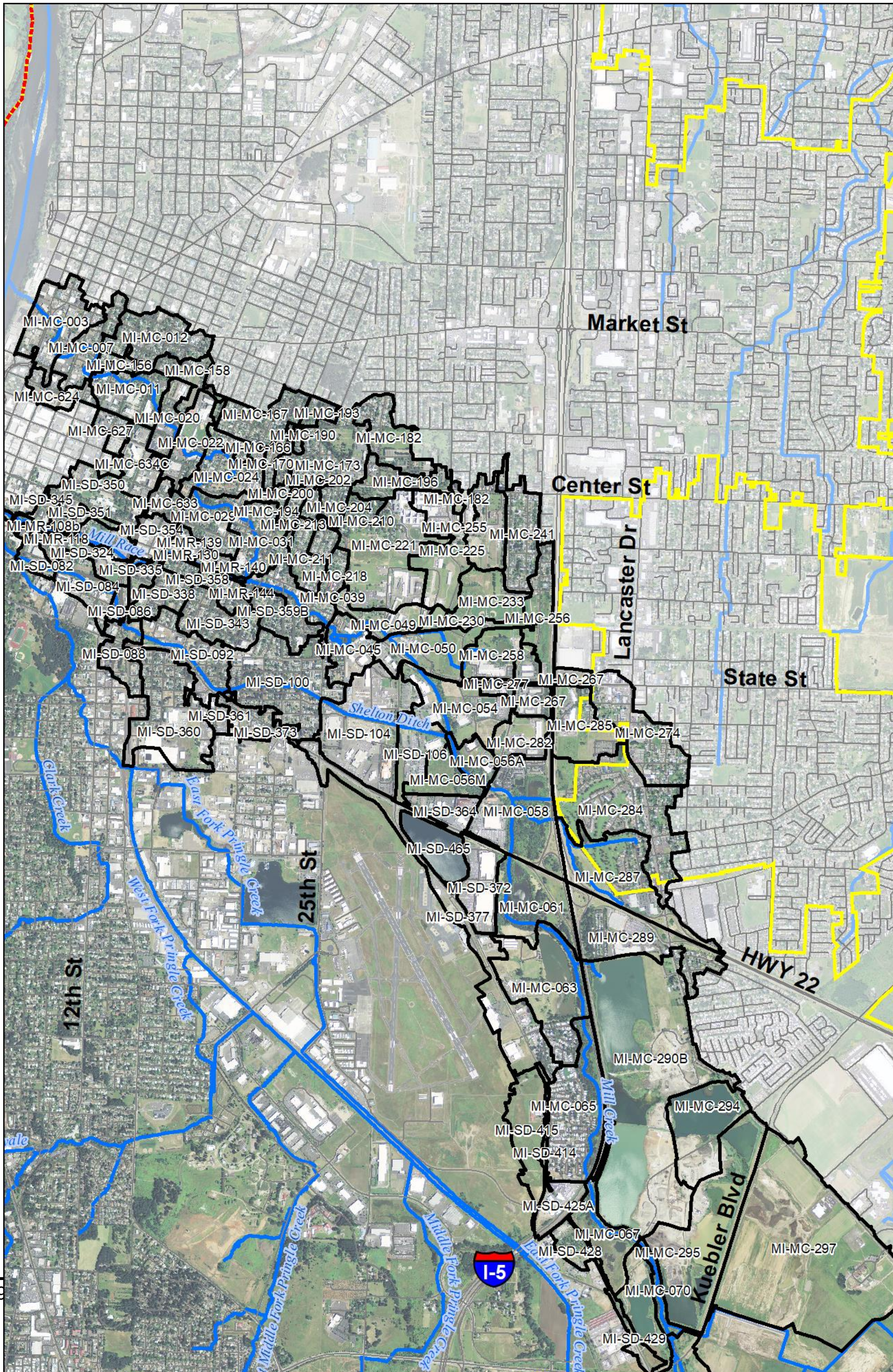
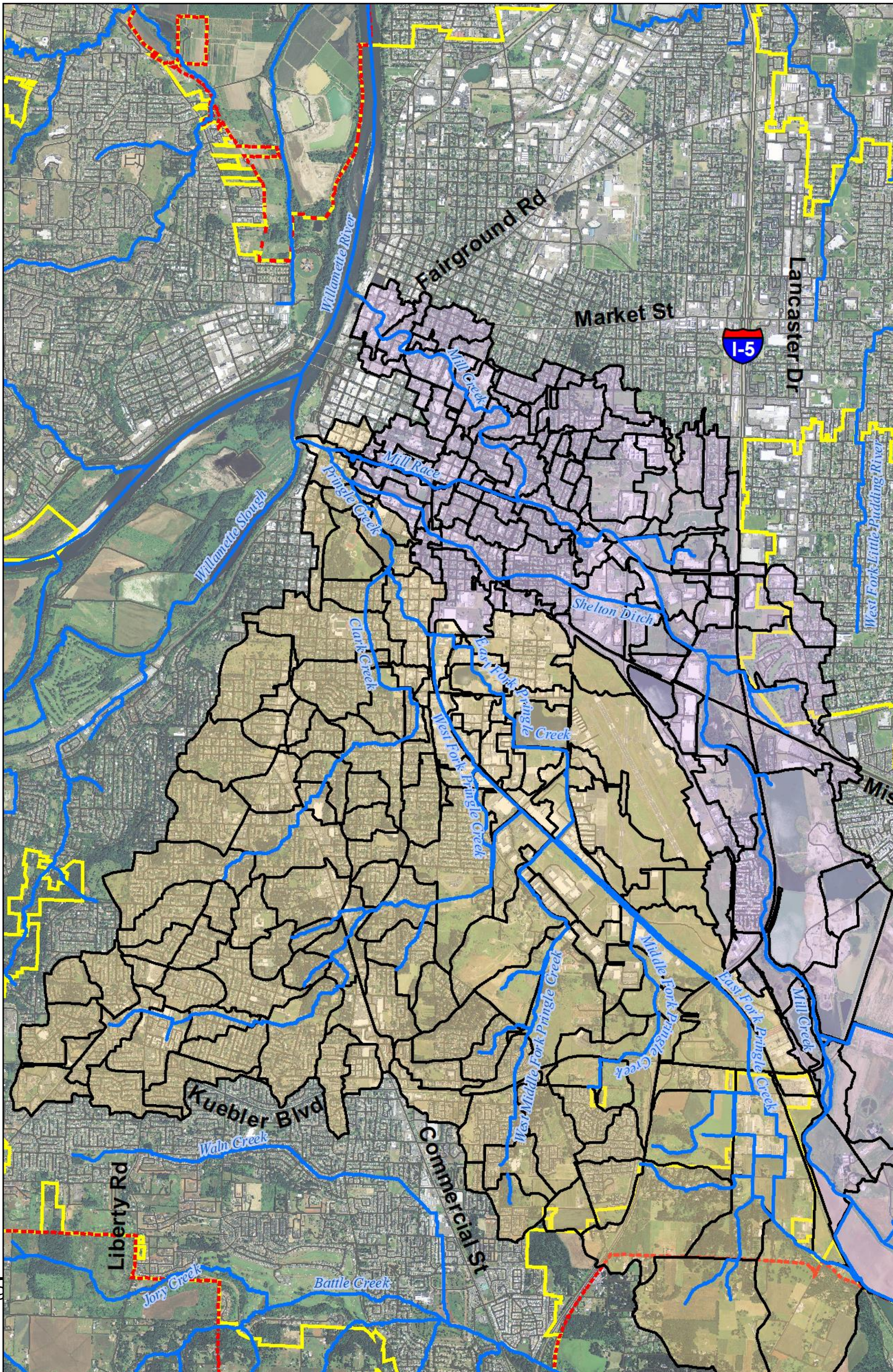

Market St
Center St
Lancaster Dr
State St
HWY 22
25th St
12th St
Kuebler Blvd
I-5
Mill Race
Shelton Ditch
Clark Creek
East Fork Pringle Creek
West Fork Pringle Creek
Middle Fork Pringle Creek
Mill Creek
MI-MC-003
MI-MC-007
MI-MC-012
MI-MC-156
MI-MC-158
MI-MC-011
MI-MC-624
MI-MC-020
MI-MC-167
MI-MC-193
MI-MC-627
MI-MC-190
MI-MC-182
MI-MC-022
MI-MC-166
MI-MC-634C
MI-MC-170
MI-MC-173
MI-SD-350
MI-MC-024
MI-MC-202
MI-MC-196
MI-SD-345
MI-MC-200
MI-MC-633
MI-MC-204
MI-SD-351
MI-MC-029
MI-MC-194
MI-MC-213
MI-MC-210
MI-MC-255
MI-MC-241
MI-MR-108b
MI-SD-354
MI-MR-118
MI-MR-139
MI-MC-031
MI-MC-221
MI-MC-225
MI-SD-324
MI-MR-130
MI-MC-211
MI-SD-082
MI-SD-335
MI-MR-140
MI-MC-218
MI-SD-358
MI-SD-084
MI-SD-338
MI-MR-144
MI-MC-039
MI-MC-233
MI-SD-086
MI-SD-359B
MI-SD-343
MI-MC-049
MI-MC-230
MI-MC-256
MI-MC-045
MI-MC-050
MI-SD-088
MI-SD-092
MI-MC-258
MI-SD-100
MI-MC-277
MI-MC-267
MI-MC-054
MI-SD-361
MI-MC-285
MI-MC-274
MI-SD-360
MI-SD-373
MI-SD-104
MI-MC-282
MI-SD-106
MI-MC-056A
MI-MC-056M
MI-SD-364
MI-MC-058
MI-MC-284
MI-SD-465
MI-MC-287
MI-SD-372
MI-MC-061
MI-SD-377
MI-MC-289
MI-MC-063
MI-MC-290B
MI-MC-065
MI-MC-294
MI-SD-415
MI-SD-414
MI-SD-425A
MI-MC-067
MI-SD-428
MI-MC-295
MI-MC-297
MI-MC-070
MI-SD-429

Figure 3 shows the resultant subbasins delineations. Of the 108 subbasins, 7 subbasins are partially located outside of the Salem City Limits and two subbasins are located partially outside of the UGB. During high flows in the Mill Creek Basin, overflows from Mill Creek enter the Pringle Creek basin. Consequently, models developed for the Mill Creek Basin and Pringle Creek Basin were merged into a single xpstorm model. The combined model extent is shown in



Fairground Rd
Market St
I-5
Lancaster Dr
Willamette River
Willamette Slough
Mill Creek
Mill Race
Pringle Creek
Shelton Ditch
Clark Creek
East Fork Pringle Creek
West Fork Pringle Creek
West Fork Little Pudding River
West Middle Fork Pringle Creek
Middle Fork Pringle Creek
East Fork Pringle Creek
Mill Creek
Kuebler Blvd
Commercial St
Waln Creek
Liberty Rd
Jory Creek
Battle Creek

Figure 4.

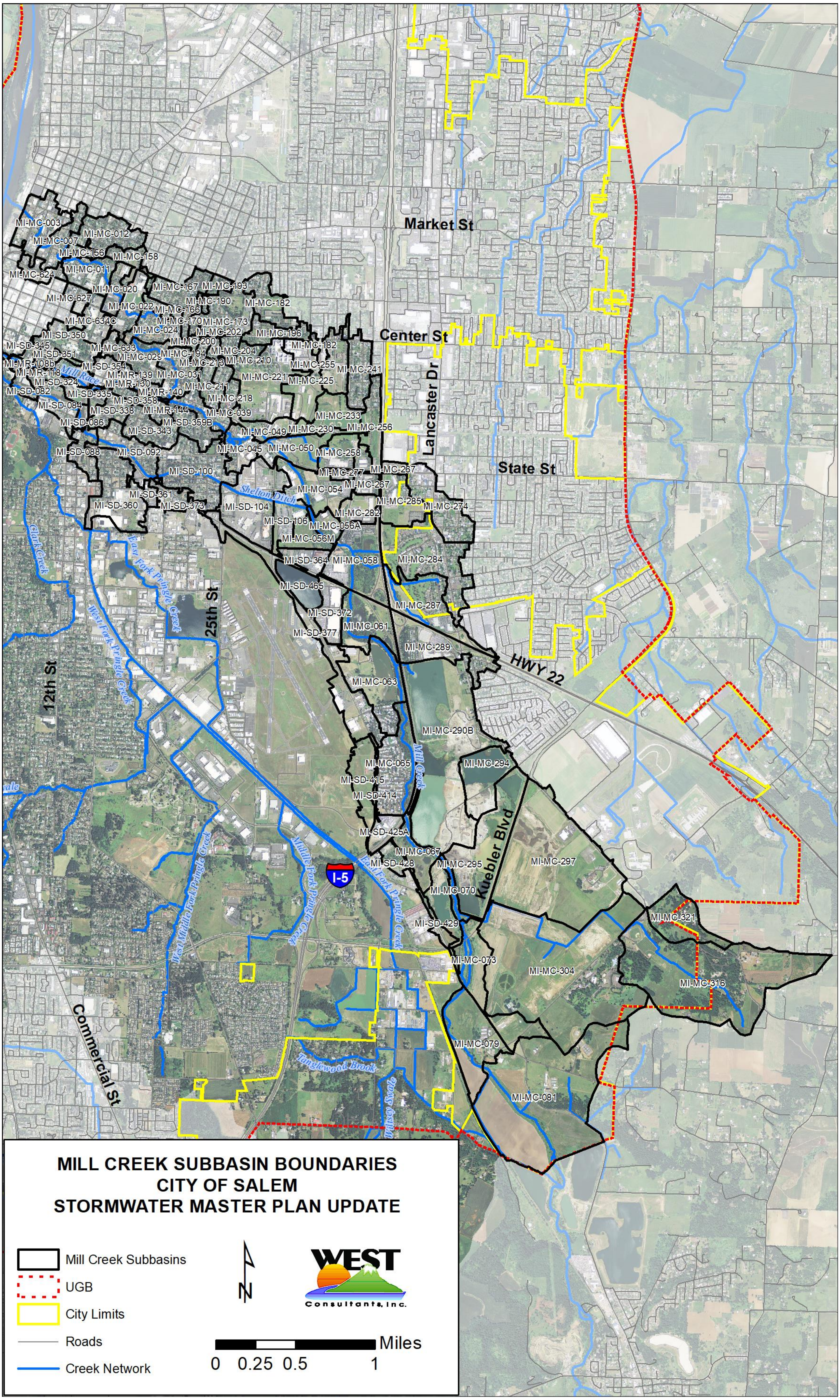


Figure 3 – Mill Creek subbasin boundaries

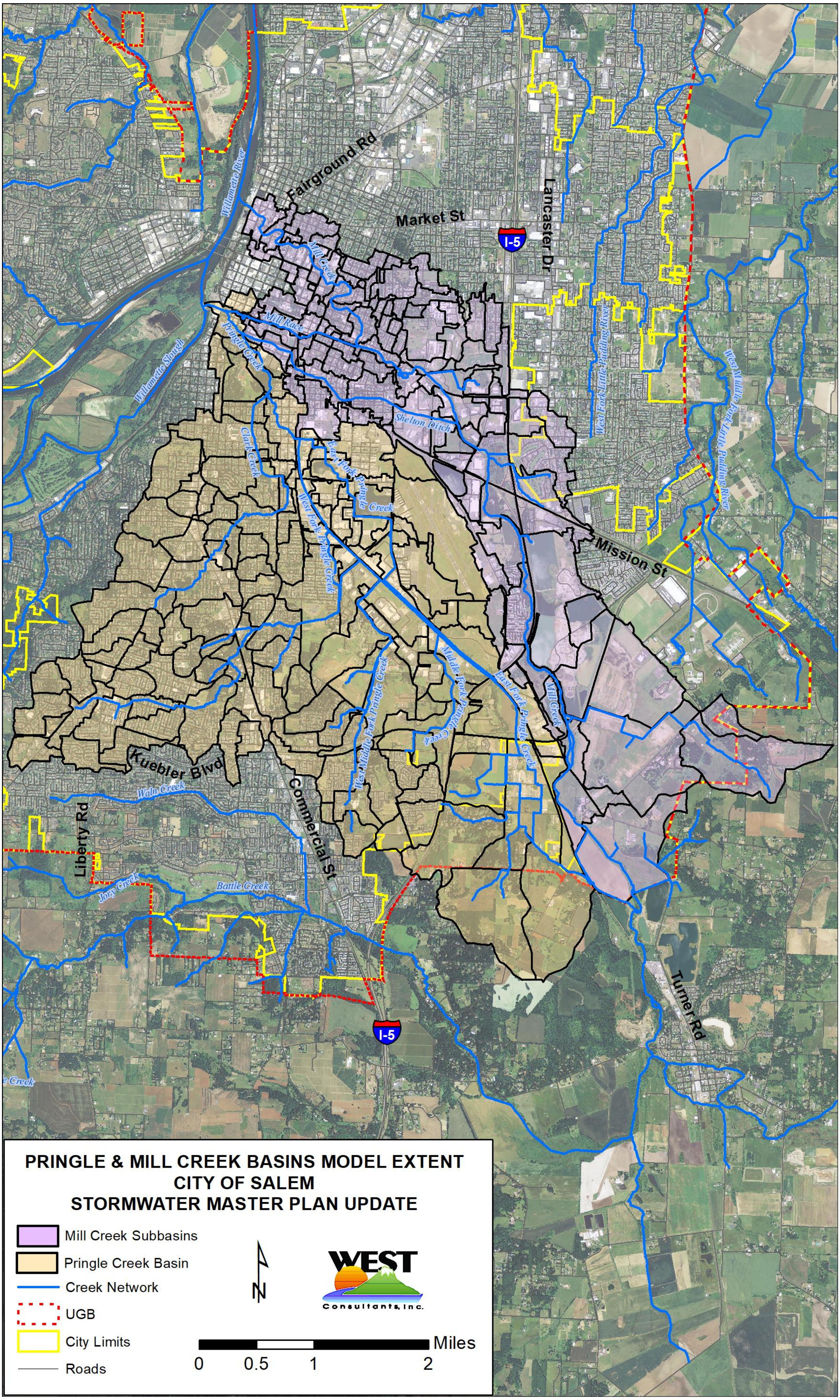


Figure 4 – Combined Mill Creek Basin and Pringle Creek Basin model extents

Watershed Characteristics Pre-Processing

The SWMM RUNOFF method of xpstorm was selected to simulate watershed hydrology due to its ability to continuously simulate non-linear soil infiltration rates via the Horton Infiltration Method. The pre-calibration watershed characteristics needed for the SWMM RUNOFF method were developed for each subbasin using the most current land cover, soil type, elevation, and impervious surface area coverage data that was either publicly available or provided by the City of Salem. Detailed descriptions of the watershed parameters used in the SWMM RUNOFF method and the processes used to develop the parameters are presented in **Appendix G** of the Stormwater Master Plan**.** A map of the Mill Creek Basin land cover classifications, which was developed from City's impervious surface data and 2011 National Land Cover Data (MRLC, 2011) is shown in **Figure 5**. A map of the hydrologic soil group classification for the Mill Creek Basin is shown in **Figure 6**. **Table 1** summarizes the name, drainage area, existing impervious surface percentage, full build-out impervious surface percentage, percent water cover, and average watershed slope of each Mill Creek subbasin.

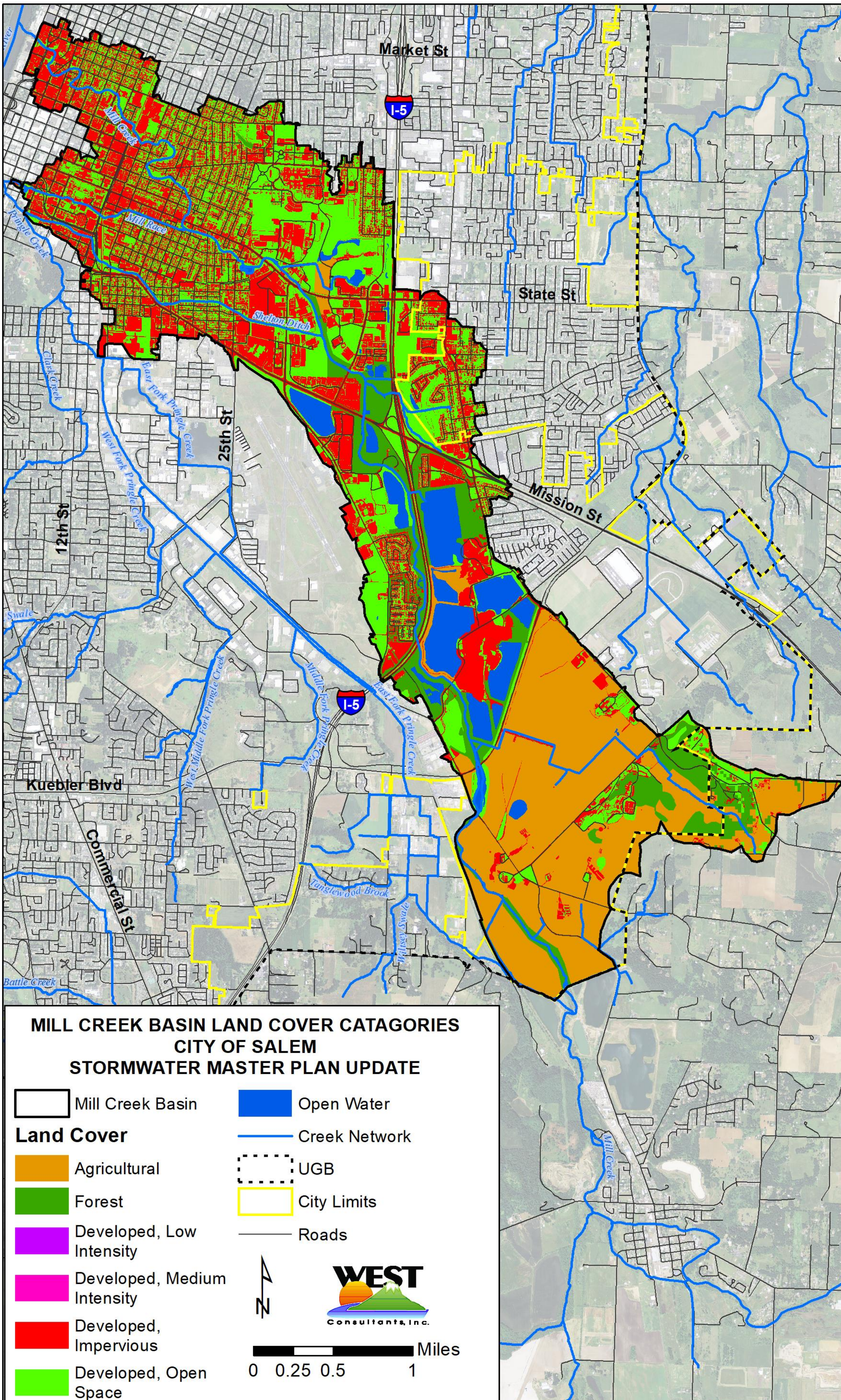


Figure 5 – Mill Creek Basin land cover categories

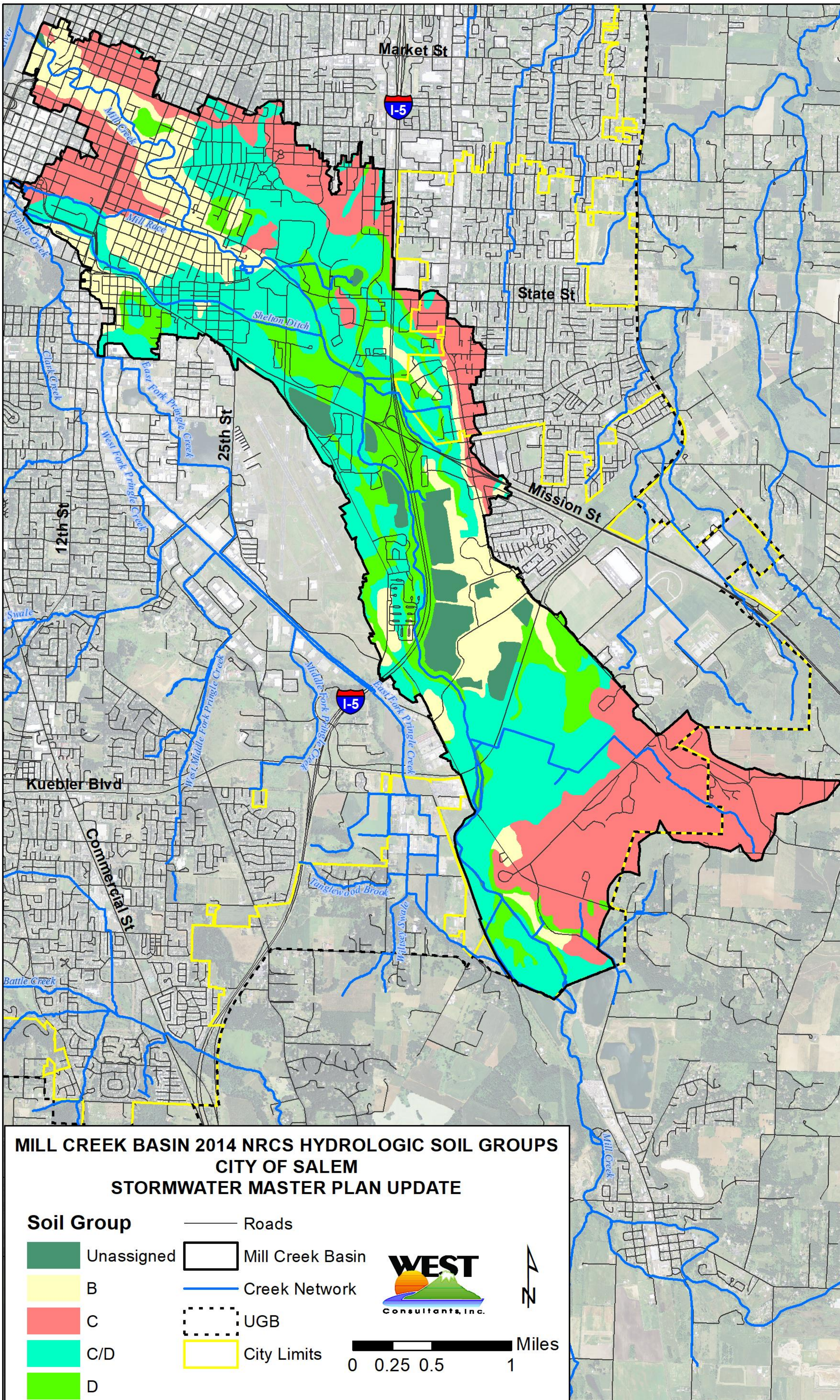


Figure 6 – NRCS 2014 hydrologic soil groups for the Mill Creek Basin

Table 1 – Mill Creek Basin watershed characteristics

Subbasin Name	Area (Acres)	Existing Directly Connected Impervious (%)	Full Build-Out Directly Connected Impervious (%)	Average Slope (%)	Water Coverage (%)
MI-MC-003	53.9	50.9	50.9	6.1	2.2
MI-MC-007	31.7	40.9	40.9	5.9	4.6
MI-MC-011	39.7	36.9	36.9	6.3	4.6
MI-MC-012	50.1	28.6	28.6	3.0	0.0
MI-MC-020	22.6	42.4	42.4	3.6	2.6
MI-MC-022	32.1	38.4	38.4	3.6	2.2
MI-MC-024	37.3	31.4	31.4	4.6	5.2
MI-MC-029	35.0	30.4	30.4	3.7	4.3
MI-MC-031	43.7	29.3	29.3	3.7	4.0
MI-MC-039	32.2	35.2	35.2	3.8	9.7
MI-MC-045	30.8	42.9	42.9	3.7	10.4
MI-MC-049	25.6	31.0	33.7	3.0	5.0
MI-MC-050	64.5	23.2	36.4	3.4	2.0
MI-MC-054	58.8	26.3	40.7	4.5	3.8
MI-MC-056A	18.9	29.6	36.3	5.4	15.2
MI-MC-056M	24.2	0.9	39.0	2.4	0.0
MI-MC-058	93.1	31.9	31.9	5.8	9.9
MI-MC-061	62.8	19.9	19.9	7.0	16.6
MI-MC-063	92.9	28.8	34.0	3.3	25.5
MI-MC-065	84.0	26.5	26.5	5.1	6.0
MI-MC-067	38.7	22.7	22.7	10.0	28.5
MI-MC-070-1	12.4	19.6	19.6	13.8	27.1
MI-MC-070-2	37.3	3.8	6.6	10.0	0.0
MI-MC-073	81.9	13.6	35.5	6.4	14.2
MI-MC-079	93.0	9.1	36.9	6.6	6.0
MI-MC-081	345.5	3.3	33.4	7.5	1.8
MI-MC-156	7.4	29.2	29.2	2.9	0.0
MI-MC-158	20.0	24.1	24.1	3.1	0.0
MI-MC-166	11.7	23.8	23.8	3.1	0.0
MI-MC-167	38.8	23.6	23.6	3.0	0.0
MI-MC-170	9.1	25.7	25.7	3.2	0.0
MI-MC-173	60.5	25.2	25.4	4.1	0.0
MI-MC-182	40.1	24.7	32.4	2.3	0.0
MI-MC-190	2.8	13.1	13.1	2.7	0.0
MI-MC-193	8.7	21.1	21.1	3.7	0.0
MI-MC-194	11.3	24.9	24.9	2.6	0.0
MI-MC-196	27.5	24.5	26.1	3.3	0.0
MI-MC-200	5.2	25.5	25.5	2.7	0.0
MI-MC-202	6.1	23.1	23.1	2.6	0.0
MI-MC-204	11.7	24.4	24.4	3.5	0.0
MI-MC-210	11.2	6.6	6.6	2.7	0.0
MI-MC-211	23.6	23.5	23.5	3.6	0.0
MI-MC-213	8.8	25.8	25.8	2.7	0.0
MI-MC-218	12.0	22.3	22.7	3.2	0.0
MI-MC-221	94.7	23.5	33.1	2.8	0.0
MI-MC-225	55.7	22.0	36.7	3.0	0.0
MI-MC-230	5.4	2.9	37.6	5.3	3.1
MI-MC-233	39.5	13.1	28.2	3.8	13.1
MI-MC-241	42.8	22.8	22.8	2.4	0.0

Table 1 – Mill Creek Basin watershed characteristics (continued)

Subbasin Name	Area (Acres)	Existing Directly Connected Impervious (%)	Full Build-Out Directly Connected Impervious (%)	Average Slope (%)	Water Coverage (%)
MI-MC-255	36.0	16.6	28.7	2.0	0.0
MI-MC-256	35.2	18.3	26.6	7.5	1.7
MI-MC-258	30.1	30.3	38.1	3.3	14.0
MI-MC-267-1	13.9	54.2	54.2	5.4	9.7
MI-MC-267-2	8.9	49.2	49.3	7.0	0.0
MI-MC-274	63.0	30.4	31.5	2.2	0.0
MI-MC-277	5.0	39.7	56.8	4.8	0.0
MI-MC-282	26.4	29.9	46.4	3.7	1.4
MI-MC-284	119.1	24.7	34.1	3.0	0.0
MI-MC-285	46.6	21.9	42.5	4.9	0.0
MI-MC-287	81.5	20.6	25.7	5.6	2.5
MI-MC-289	76.1	34.4	35.3	4.7	0.0
MI-MC-290B	293.7	40.6	45.3	5.7	46.7
MI-MC-294	63.9	44.4	44.4	6.4	52.3
MI-MC-295	132.7	39.4	39.4	9.3	47.4
MI-MC-297	293.3	4.5	35.5	2.8	0.1
MI-MC-304	417.3	4.3	34.9	7.2	1.6
MI-MC-316	318.1	2.6	17.6	14.9	0.0
MI-MC-321	59.6	2.9	21.1	12.9	0.0
MI-MC-624	19.3	57.3	57.3	2.1	0.0
MI-MC-627	12.1	51.7	51.7	2.4	0.0
MI-MC-633	13.4	41.8	41.8	2.4	0.0
MI-MC-634C	27.0	45.7	45.7	3.8	0.0
MI-MR-108b	4.0	23.1	23.1	9.4	14.8
MI-MR-118	19.1	32.3	32.3	6.3	6.6
MI-MR-130	8.0	47.0	47.0	3.9	7.2
MI-MR-139	5.4	46.1	46.1	2.4	0.4
MI-MR-140	3.2	51.0	51.0	3.1	5.9
MI-MR-144	1.5	33.2	33.2	7.2	19.3
MI-SD-082	13.7	44.2	44.2	5.8	7.7
MI-SD-084	29.1	46.0	46.0	6.6	5.9
MI-SD-086	6.7	51.1	51.1	9.3	12.4
MI-SD-088	26.6	34.1	34.1	6.5	2.2
MI-SD-092	49.4	36.5	36.5	6.7	5.4
MI-SD-100	92.9	26.9	26.9	3.7	1.8
MI-SD-104	99.6	50.1	50.2	3.3	1.6
MI-SD-106	31.4	34.6	37.7	5.9	3.6
MI-SD-324	25.8	40.6	40.6	3.5	0.0
MI-SD-335	11.4	27.0	27.0	2.9	0.1
MI-SD-338	22.1	28.1	28.1	2.2	0.0
MI-SD-343	39.1	30.1	30.1	2.7	0.0
MI-SD-345	6.8	51.6	51.6	2.6	0.0
MI-SD-350	42.4	33.2	33.2	3.9	0.0
MI-SD-351	10.3	36.0	36.0	4.1	0.0
MI-SD-354	18.8	53.3	53.3	2.4	0.1
MI-SD-358	7.3	23.6	23.6	4.2	0.0
MI-SD-359B	40.5	27.0	27.0	2.4	0.0
MI-SD-360	84.1	30.5	38.0	2.2	0.0
MI-SD-361	7.6	52.0	52.0	2.7	0.0

Table 1 – Mill Creek Basin watershed characteristics (continued)

Subbasin Name	Area (Acres)	Existing Directly Connected Impervious (%)	Full Build-Out Directly Connected Impervious (%)	Average Slope (%)	Water Coverage (%)
MI-SD-364	23.9	51.9	52.4	3.4	0.0
MI-SD-372	37.6	56.5	56.5	3.3	0.2
MI-SD-373	22.2	43.8	43.8	2.4	0.0
MI-SD-377	96.7	32.1	33.7	3.4	0.0
MI-SD-414	6.2	19.9	19.9	6.3	0.0
MI-SD-415	44.4	2.5	2.5	2.5	0.3
MI-SD-425A	21.5	39.3	39.3	5.9	0.0
MI-SD-428	14.5	7.6	32.8	5.0	0.0
MI-SD-429	16.7	18.5	32.4	6.8	0.0
MI-SD-465	31.8	63.3	63.3	3.1	90.4

Mill Creek Basin Flood Warning System Modeling

For the portion of the Mill Creek basin that is located upstream of the detailed study area, an existing HEC-HMS 4.1 (USACE, 2009) hydrologic model, that was developed for the Mill Creek Flood Warning System (WEST, 2016), was used to develop existing conditions and full-buildout design flows. The portion of the drainage basin located upstream of MIC 12 streamflow gauge was divided into 25 subbasins and initial and constant infiltration method, developed from soil survey data (NRCS, 2014), was used for computing runoff. Impervious data was developed using the National Land Cover Data (MRLC, 2011). The ModClark method was used for the rainfall-runoff transformation and the TR-55 (NRCS, 1986) methodology was used for calculating the time of concentration. Two methods were used for hydrologic flow routing. For reaches in the upper basin in which backwater has less influence, the Muskingum-Cunge method was used. For reaches lower in the basin, a HEC-RAS 5.0.0 (USACE, 2015) hydraulic model was used to develop Modified Pulse rating tables to help account for backwater effects. Rainfall data for the model came from the City of Salem rainfall gauge network. Data for each subbasin was obtained from the gauge located nearest to each subbasin centroid. The hydrologic model was calibrated using the January 2012, early December 2015, and late December 2015 storm events.

Rainfall Data Collection and Processing

Historic rainfall data are available for several gauges located in and near the Mill Creek Basin detail study area, including gauges: RG2, RG7, RG9, RG18, RG19, RG24, and McNary Field. Additional rain gauges are available for the portion of Mill Creek Basin upstream of the Salem City Limits, including BEA3, RG8, RG11, RG14, RG15, RG51, RG52, RG53, RG54, RG55, and RG56. All of the gauges are operated by the City of Salem, except for the McNary Field gauge, which is operated by the National Oceanic and Atmospheric Administration (NOAA). Gauges were assigned to individual subbasins within the model based on both proximity to the subbasin centroid as well as orographic similarities. **Table 2** contains a description of each rainfall gage used in the Mill Creek Basin. **Figure 7** shows the location of the rainfall gauges used in the Mill Creek Basin detailed study area model and the subwatersheds assigned to each rainfall gauge.

Table 2 – Mill Creek Basin rainfall gauges

Gauge	Owner	Location	Period of Record	Elevation	Record Increment	# of Mill Creek Subbasins Assigned to Gauge	
						Detailed Study Area	Upper Basin
McNary Field (KSLE)	NOAA	Salem Airport (McNary Field)	1948 - Present	205 ft	1-hour	0 of 108	0 of 25
Rain Gauge 2 (RG2)	City of Salem	Between 20th Street SE and 22nd Street SE, 400 feet south of Mission Street	1996 - Present	183 ft	15-minute	39 of 108	1 of 25
Rain Gauge 7 (RG7)	City of Salem	Near Mirror Pond between Liberty and Commercial Street	1996 - Present	165 ft	15-minute	9 of 108	0 of 25
Rain Gauge 8 (RG8)	City of Salem	Upstream of the Commercial Street crossing of Battle Creek	1996 - 1998 & 2002 - Present	389 ft	15-minute	0 of 108	3 of 25
Rain Gauge 9 (RG9)	City of Salem	Immediately downstream of the MacLeay Road crossing of the West Middle Fork Little Pudding River	1997 - Present	212 ft	15-minute	4 of 108	0 of 25
Rain Gauge 10 (RG11)	City of Salem	Southeast of the Davis Road and Skyline Drive intersection	1998 - 2006 & 2008 - Present	730 ft	15-minute	0 of 108	1 of 25
Rain Gauge 14 (RG14)	City of Salem	Turner Fire Station	2001 - Present	282 ft	15-minute	0 of 108	3 of 25
Rain Gauge 15 (RG15)	City of Salem	Geren Island	2002 - Present	460 ft	15-minute	0 of 108	2 of 25
Rain Gauge 18 (RG18)	City of Salem	North Salem High School	2003 - Present	162 ft	15-minute	34 of 108	1 of 25
Rain Gauge 19 (RG19)	City of Salem	East of the I-5 at Turner Road overpass	2005 - Present	222 ft	15-minute	16 of 108	1 of 25
Rain Gauge 24 (RG24)	City of Salem	Near the Mill Creek Correctional Facility on Turner Road	2008 - Present	306 ft	15-minute	6 of 108	1 of 25
Rain Gauge 51 (RG51)	City of Salem	Aumsville Rural Fire Station	2011 - Present	420 ft	15-minute	0 of 108	2 of 25
Rain Gauge 52 (RG52)	City of Salem	Cascade High School	2011 - Present	335 ft	15-minute	0 of 108	3 of 25
Rain Gauge 53 (RG53)	City of Salem	On Boedigheimer Road, east of the City of Sublimity	2014 - Present	640 ft	15-minute	0 of 108	1 of 25
Rain Gauge 54 (RG54)	City of Salem	On Coon Hollow Road, east of 170th Street SE	2014 - Present	951 ft	15-minute	0 of 108	2 of 25
Rain Gauge 55 (RG55)	City of Salem	On Cater Road, just south of the Silver Falls Highway	2014 - Present	885 ft	15-minute	0 of 108	1 of 25
Rain Gauge 56 (RG56)	City of Salem	On Continental Drive, west of Ridgeway Drive	2014 - Present	475 ft	15-minute	0 of 108	1 of 25
Rain Gauge Beaver Creek 3 (BEA3)	City of Salem	West of Aumsville, along Beaver Creek, downstream of Olney Road	2014 - Present	340 ft	15-minute	0 of 108	2 of 25

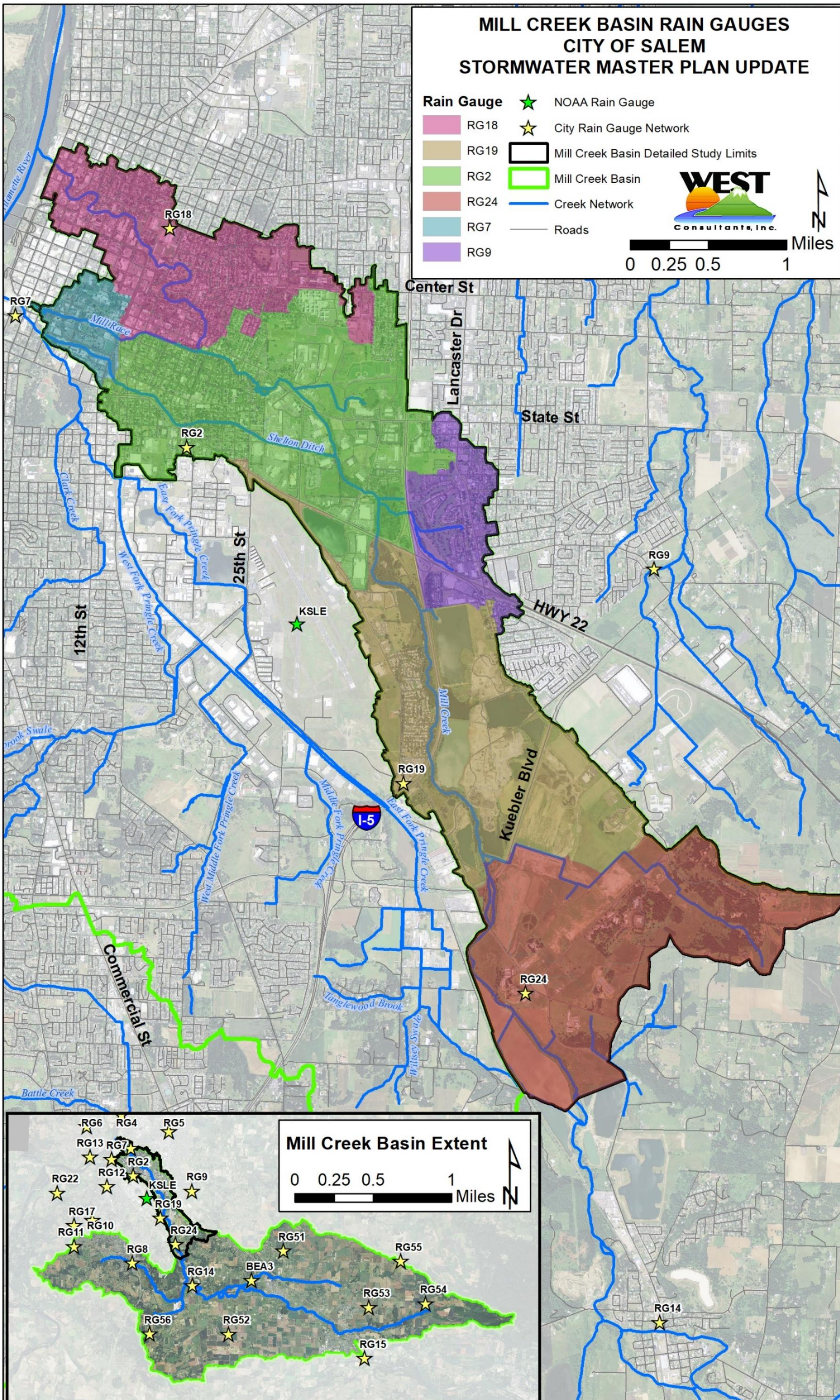


Figure 7 - Mill Creek rainfall gauge locations and assigned subbasins

Design Storm Development

While the City of Salem Design Standards recommends the 24-hour SCS Type-1A storm distribution (City of Salem, 2014), initial modeling suggested that this distribution was inadequate for a basin wide model. Therefore, an evaluation of available rainfall data was conducted to determine the most appropriate design storms for use in the City of Salem SWMP Update. Ultimately, a 100-yr, 48-hr design storm using a normalized distribution based on a November 1996 event was recommended for evaluation of the flood risk within the Battle Creek basin. A rainfall frequency analysis of the McNary Field rainfall gauge was used to developed base design storm depths. A comparative analysis of the rain gauge data was performed to develop a relationship between city rain gauges that are in close proximity to Mill Creek Basin and the McNary Field rain gauge. A detailed description of the storm distribution analysis, rainfall frequency analysis, and rainfall gauge comparative analysis for Mill Creek Basin is located in **Appendix 11.B**.

Mill Creek Inflow Development

The portion of the Mill Creek Basin modeled in detail with the xpstorm model represents approximately 8.3 square miles of the 111 square mile basin. For the calibration events, inflows for Mill Creek recorded at the MIC 12 streamflow gauge were used. However, for the existing and full build-out design events, the inflows were developed using the HEC-HMS Mill Creek Flood Warning System hydrologic model (WEST, 2016) discuss previously.

For the existing conditions HEC-HMS model, the 48-hour design event rainfall distribution was used. Adjustments to the rainfall depths were made for each subbasin based on the subbasin's proximity to a city operated rain gauge and that rain gauge's historic proportional relationship to the McNary Field rainfall gauge.

The Army Corps of Engineers Statistical Software Package (HEC-SSP) (USACE, 2016) was used to perform a USGS Bulletin 17B flood frequency analysis on existing Mill Creek annual peak streamflow data. The analysis utilized the combined data from the MIC 12 streamflow gauge and the inactive Mill Creek at Penitentiary Annex USGS streamflow gauge (14191500). The 2-, 5-, 10-, 25-, and 50-year design storm outflow hydrographs from the HEC-HMS model were proportionally adjusted to match the peak flows from the HEC-SSP flood frequency analysis. The 100-year design storm outflow hydrograph from the HEC-HMS model was proportionally adjusted to match the 100-year peak flow from Marion County's Federal Emergency Management Agency (FEMA) Flood Insurance Studies (FIS) (FEMA, 2003). This was done to maintain consistency with the effective FEMA study and because the HEC-SSP results were similar to the FEMA peak flow value. The full build-out conditions design storm hydrographs from HEC-HMS were similarly adjusted using the same ratios as the existing conditions hydrographs. The resulting peak inflows for Mill Creek, at the MIC 12 streamflow gauge, used in the xpstorm model for exiting and full buildout conditions are shown in **Table 3**.

Table 3 – Mill Creek detailed study area peak inflows for existing and full build-out conditions

Recurrence Interval (years)	Mill Creek Peak Inflows (cfs)	
	Existing Conditions	Full Buildout Conditions
100	9,540	9,576
50	8,470	8,503
25	7,170	7,203
10	5,598	5,622
5	4,489	4,513
2	3,032	3,055

Hydraulics Component Development

The development of the Hydraulic component of the xpstorm model included:

- Hydraulic Model Extent
- Data Collection and GIS Database Compilation
- Link Modeling Methods
- Node Modeling Methods
- Two-Dimensional Modeling
- Outfall Conditions

For a detailed description of the hydraulic modeling methods used for developing the Mill Creek Basin model, refer to **Appendix H** of the Stormwater Master Plan.

Hydraulic Model Extent

While the upstream extent of the Mill Creek Basin detailed study area is the Salem City Limits, the actual hydraulic model was extended and additional 4,000-ft upstream to the railroad crossing of Mill Creek. This allowed the hydraulic model to capture the overflows into the East Fork Pringle Creek that occur when high water from Mill Creek backflows through both a small drainage channel and a 2.5-ft diameter irrigation culvert. It was assumed that the Mill Creek flows at the upstream boundary of the model were the same as those developed for the Mill Creek 12 gauge site.

Data Collection and GIS Database Compilation

Much of the required pipe and culvert data was available either in the City's Hanson asset management database, the City's storm sewer GIS data, or as-built drawings. However, site visits were required for some areas to verify and collect data for portions of the Pringle Creek Basin drainage network. A small portion of West

Fork Pringle Creek, East Fork Pringle Creek, West Middle Fork Pringle Creek, Pringle Creek, and Clark Creek were contained in existing HEC-RAS models, which provided necessary channel, bridge, and control structure data. Data had to be gathered through field work and surveys for bridges, control structures, and channels not contained in the HEC-RAS models. Elevation data for areas located outside of the UGB and in drainage areas less than 1 square mile were developed from available LiDAR data (Watershed Concepts, 2009). Likewise, dimensions of hydraulic structures located outside of the UGB and in drainage areas less than 1 square mile were either determined in the field with a tape measure or estimated.

Portions of the Mill Creek drainage network contained within the UGB and having a drainage area greater than 1 square mile were designated as being high priority in discussions with the City. For these areas detailed survey data and measurements were collected for cross sections, bridges, control structures, culverts, and pipe systems not available in HEC-RAS models, the Hansen asset management database, the City's storm sewer GIS data, or as-built drawings. Topographic data for high priority ditches without dense vegetation was extracted from the LiDAR data.

Survey data and measurements were collected for 56 bridges, 171 cross sections, 26 culverts, 7 storm sewer pipes, and 6 control structures. Surveyed cross sections were extended through the dense vegetation for some distance beyond the top of bank. If the cross section needed to be extended beyond this point, the data was extracted from the available LiDAR (Watershed Concepts, 2009) and merged with the field survey data. Topographic data for ditches with minimal vegetation were collected using LiDAR data. **Figure 8** shows the data sources for the open channels within Mill Creek Basin.

Data for areas located outside of the Urban Growth Boundary and in drainage areas less than 1 square mile were developed from available LiDAR data. Dimensions of hydraulic structures were either measured in the field or estimated.

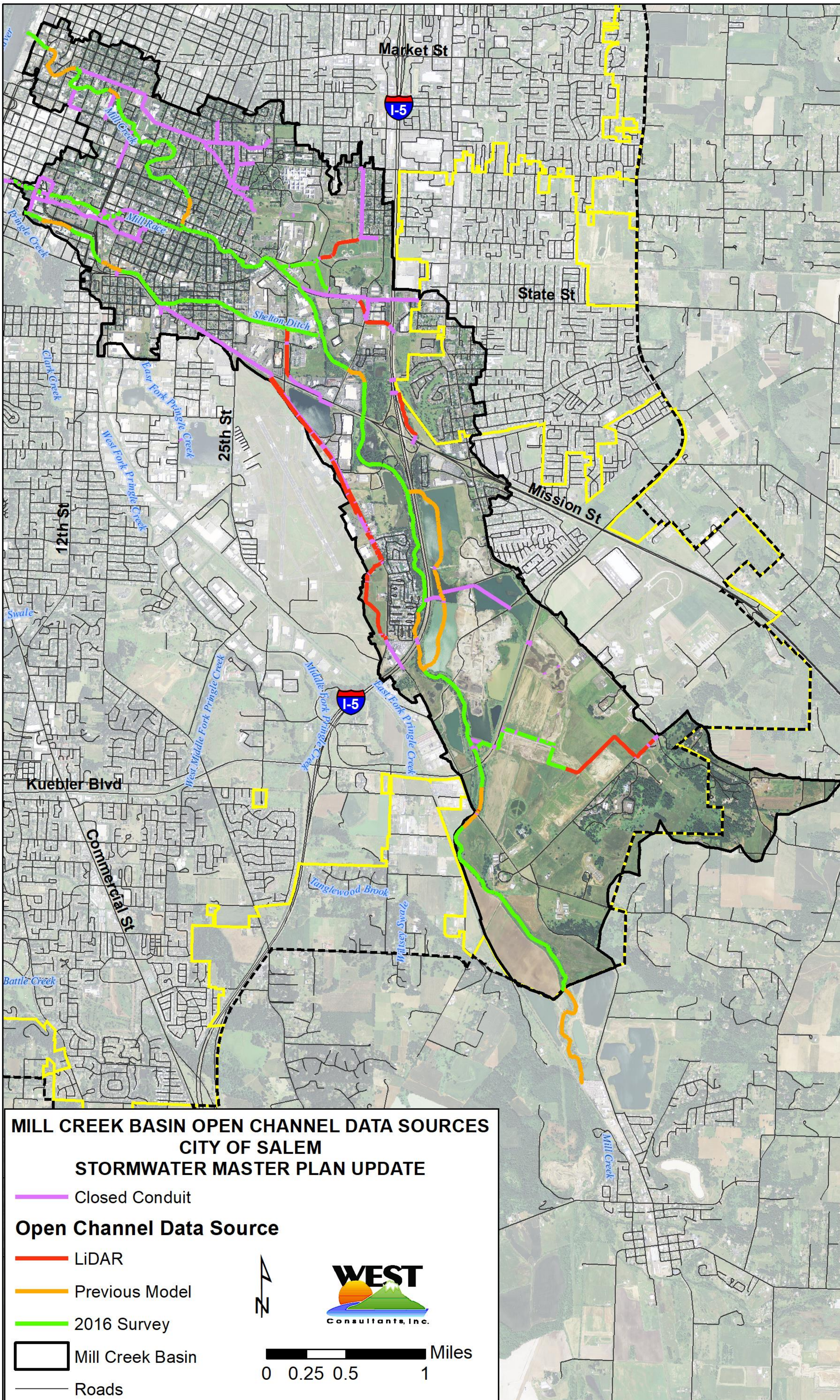


Figure 8 – Mill Creek Basin open channel data sources

Link and Node Modeling Methods

The hydraulic conveyance routes in the xpstorm model are represented by features defined as links and nodes. Nodes represent manholes, junctions, confluences, and storage areas. The modeling methodologies and techniques used when developing the nodes are described in **Appendix H** of the Stormwater Master Plan. Specific nodes in the model were named using the following convention: The first two letters in the node name indicate the primary drainage basin it is located in (e.g., MI for Mill Creek). The third and fourth letters in the name refer to the subbasin in which the node is located (e.g. MC for Mill Creek or SD for Shelton Ditch). The last three numbers are a unique identifier of the node. For example, MI-SD-078 is node number 078 located in the Shelton Ditch (SD) subbasin within the Mill Creek Basin (MI).

Links in the xpstorm model represent channels, pipes, bridges, culverts, and control structures. The modeling methodologies and techniques used when developing the links are described in **Appendix H** of the Stormwater Master Plan**.** The naming convention for links is based on the upstream node identifier, except it uses lower case lettering and no hyphen between the basin and creek identifiers. For example, misd-078 is link 078, located just downstream of node number 78, along Shelton Ditch, in the Mill Creek Basin. For overflow links, an "o" was placed at the end of the link name. **Figure 9** through

HWY 22
Turner Rd
I-5
Mill Creek
Kuebler Blvd
36th Ave
View Extent
The reach of Mill Creek upstream of Turner Road was not included in the design event hydraulic model.
MI-MC-065
MI-MC-065a
MI-MC-065b
MI-MC-065c
MI-MC-065h
MI-MC-066
MI-MC-067
MI-MC-067a
MI-MC-067b
MI-MC-068
MI-MC-068a
MI-MC-069
MI-MC-070
MI-MC-070a
MI-MC-071
MI-MC-072
MI-MC-073
MI-MC-074
MI-MC-075
MI-MC-075b
MI-MC-075c
MI-MC-076
MI-MC-077
MI-MC-078
MI-MC-294
MI-MC-295
MI-MC-296
MI-MC-296a
MI-MC-296b
MI-MC-296c
MI-MC-296d
MI-MC-297
MI-MC-300
MI-MC-301
MI-MC-302
MI-MC-303
MI-MC-304
MI-MC-305
MI-MC-306
MI-MC-306a
MI-MC-307
MI-MC-308
MI-MC-309
MI-MC-310
MI-MC-310a
MI-MC-310b
MI-MC-311
MI-MC-312
MI-MC-312a
MI-MC-312b
MI-MC-623
MI-SD-414
MI-SD-416
MI-SD-417
MI-SD-418
MI-SD-419
MI-SD-419a
MI-SD-419b
MI-SD-420
MI-SD-422
MI-SD-423
MI-SD-424
MI-SD-426
MI-SD-427
MI-SD-428
MI-SD-429

Figure 11 shows the link and node network developed for the xpstorm model.

Two-Dimensional Modeling

The Mill Creek Basin is relatively flat and prone to flooding in multiple areas. The complex flow patterns that occur in the wide floodplains necessitated the use of the two-dimensional (2-D) modeling component of xpstorm. Various grid cell sizes were tested to find the optimum balance of accuracy and model runtime. Ultimately, a 2-D computational grid, with 20-ft by 20-ft cells, containing approximately 650,000 cells was defined. The extent of the 2-D grid and the land cover types used to assign the 2-D overland roughness values is provided in **Figure 12**.

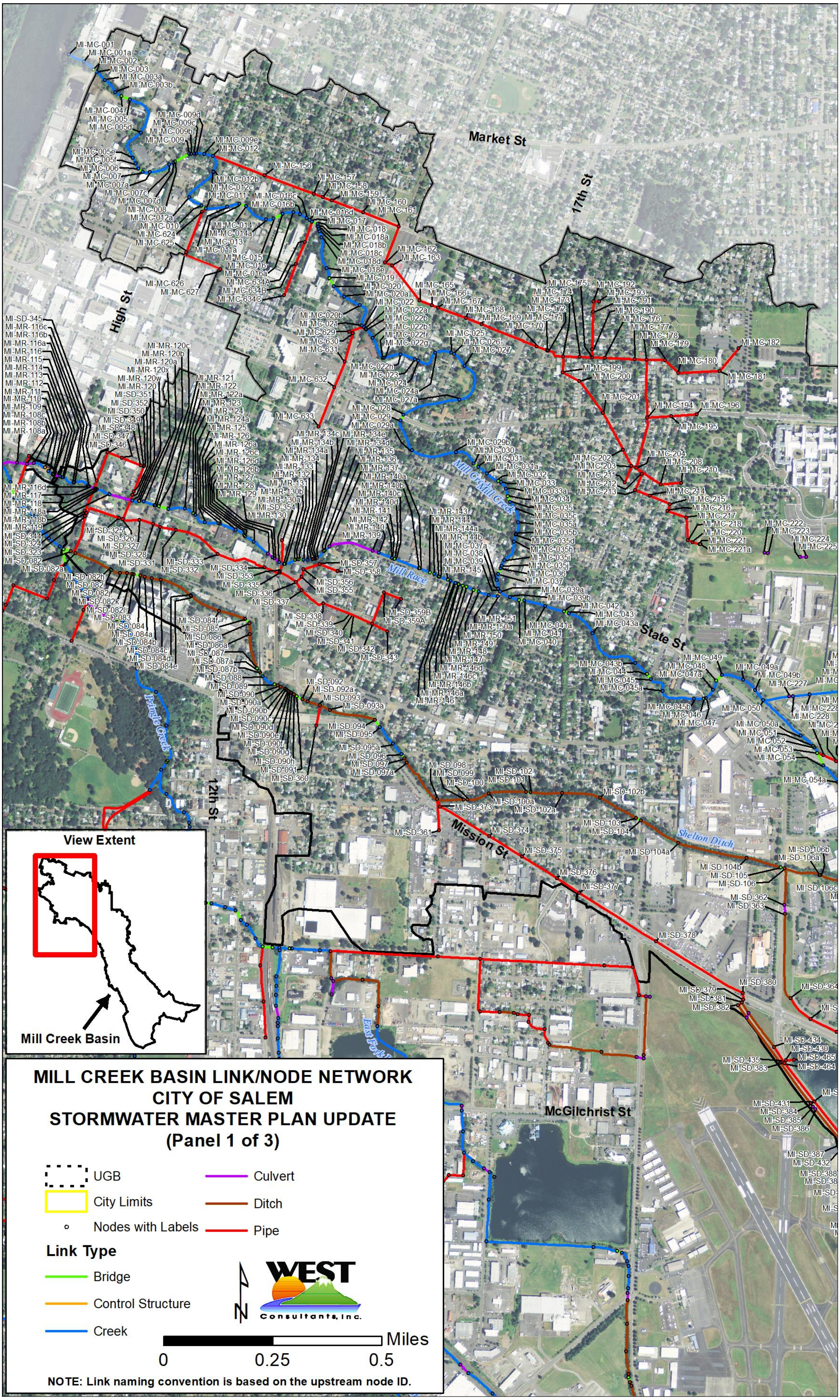


Figure 9 – Mill Creek Basin xpstorm link and node network (1 of 3)

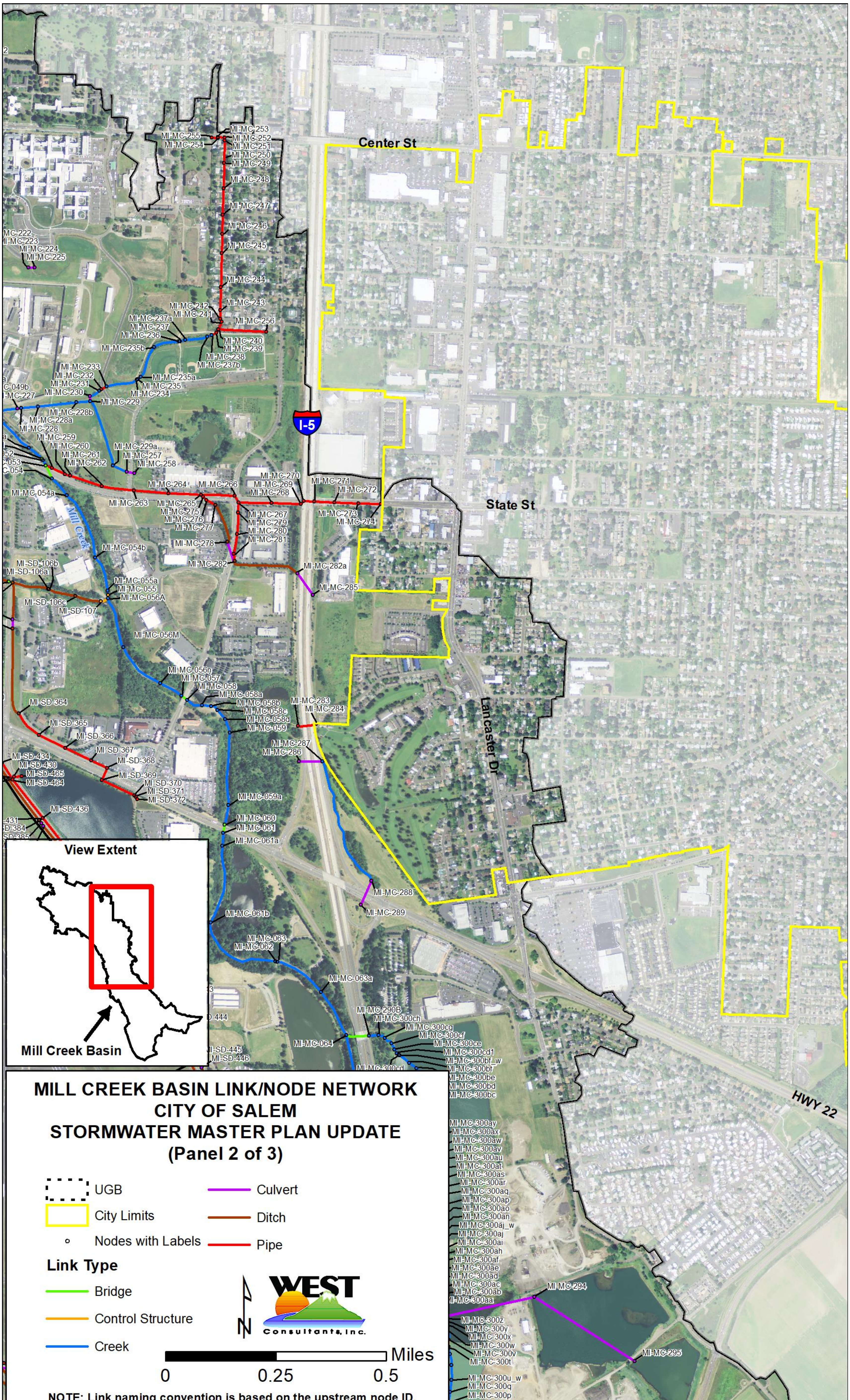


Figure 10 – Mill Creek Basin xpstorm link and node network (2 of 3)

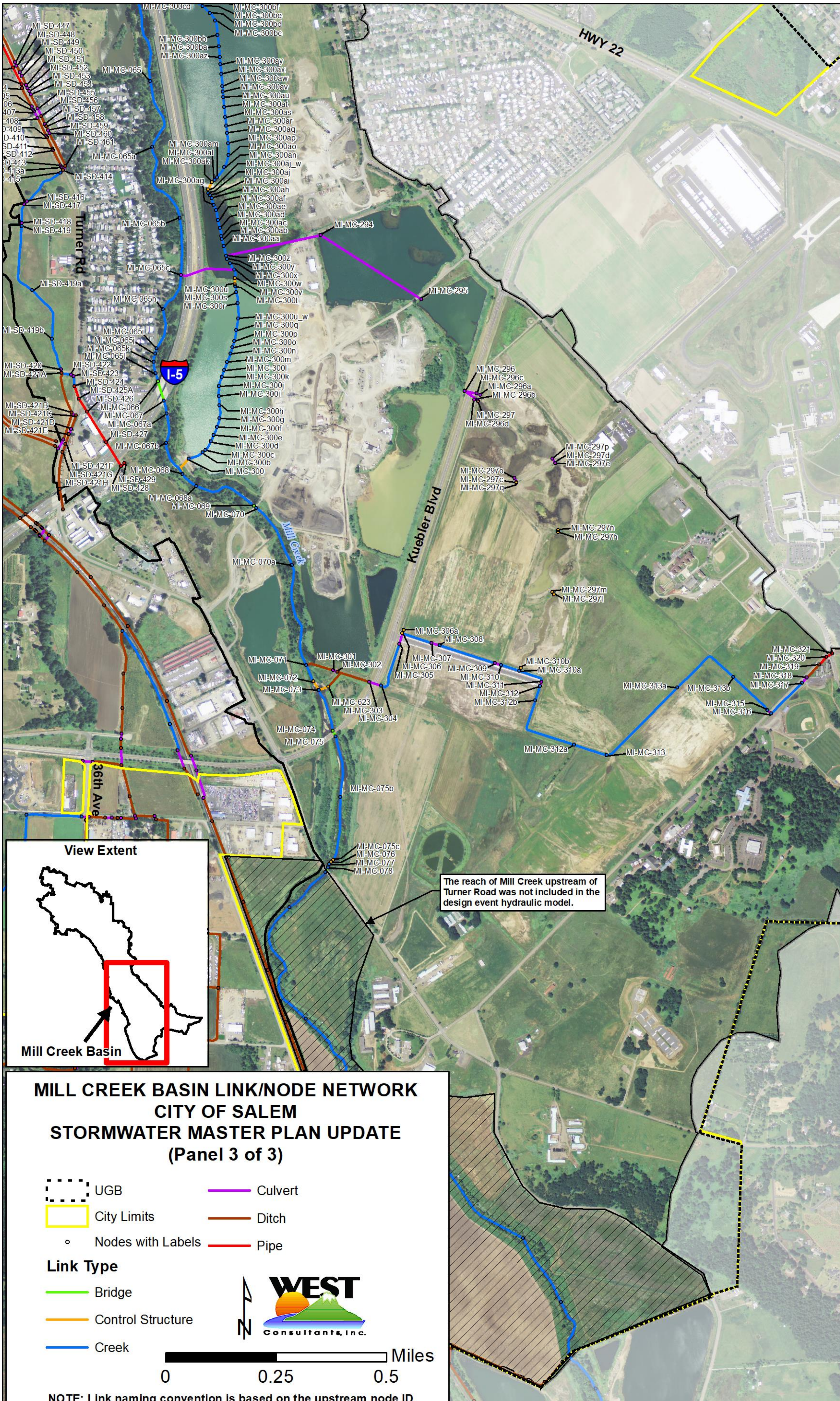


Figure 11 – Mill Creek Basin xpstorm link and node network (3 of 3)

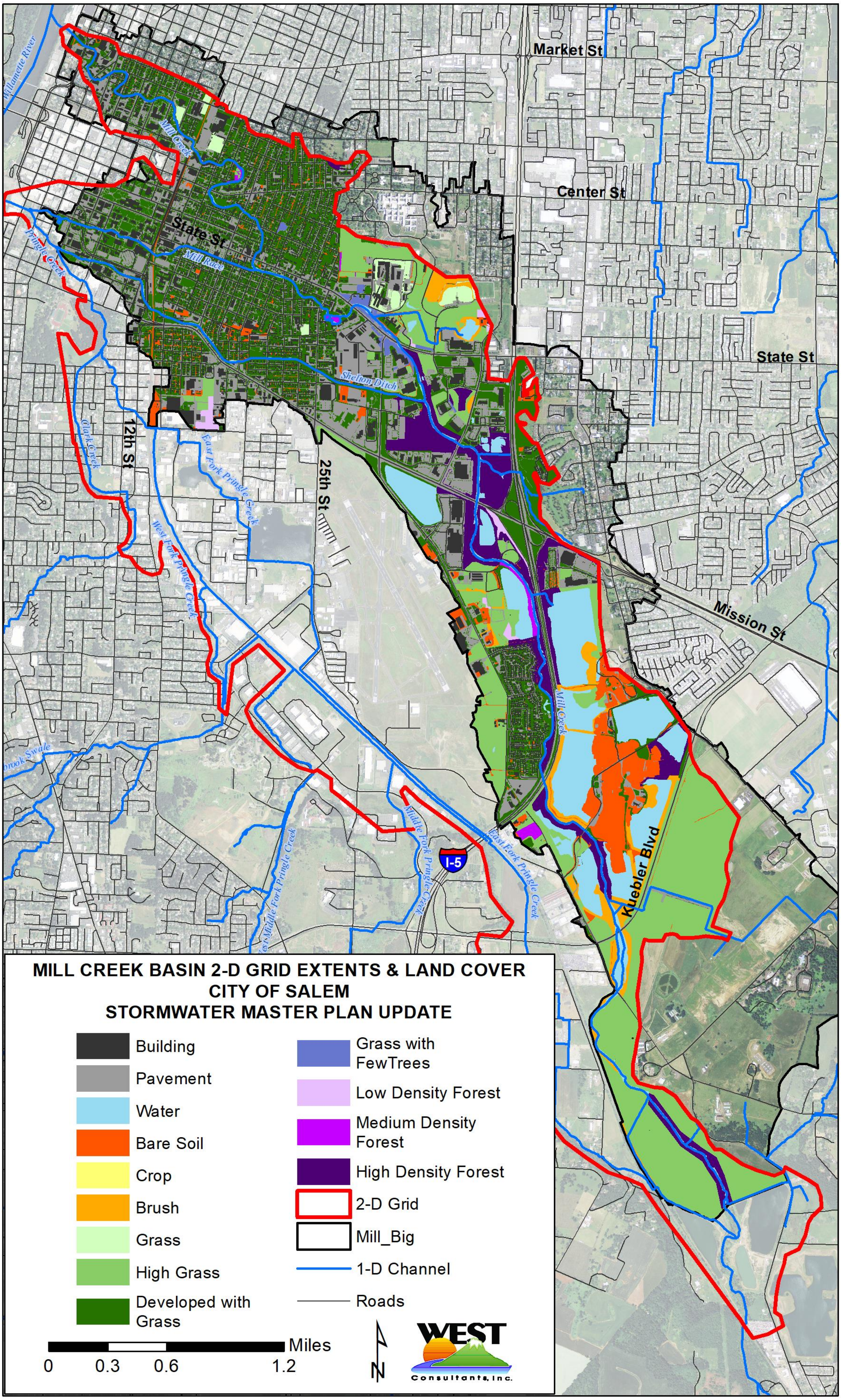


Figure 12 – Mill Creek Basin 2-D grid extents and land cover

Outfall Conditions

Mill Creek outfalls into the Willamette River, approximately 0.5 miles downstream of the USGS streamflow gauge Willamette River at Salem (USGS 14191000). To model calibration storm events, the Mill Creek outfall was assigned a stage time series based on 1-hour adjusted stage data from the USGS streamflow gauge. The observed stages at the gauge were adjusted using the Willamette River's 100-year water surface profile slope from Marion County's FIS (FEMA, 2003). The resulting -1.53 ft stage adjustment accounts for the elevation decrease between the USGS gauge location and the Mill Creek outfall.

For the Mill Creek Basin design storm events, the outfall stage was developed using guidance from the Hydraulic Engineering Circular No. 22, 3rd Edition (HEC-22) (HEC, 2009). When a creek with a relatively small drainage area outfalls into a river with a relatively large drainage area the coincidental probability of a flood event occurring in both hydrologic systems at the same time should be considered when determining the appropriate outfall conditions. HEC-22 provides coincidental outfall recommendations based on the drainage area ratio of the main stream and the tributary.

Willamette River recurrence interval peak flows were developed by the US Army Corps of Engineers and published in Flood Frequency Curves for the Willamette River and its Major Tributaries Upstream of Salem, Oregon (USACE, 2014). The flows were converted to stages using the Willamette River at Salem USGS streamflow gauge stage-discharge rating curve. The developed stages were adjusted by -1.53 ft to accounts for the elevation decrease between the USGS gauge and the Mill Creek outfall. The resulting Willamette River recurrence interval outfall conditions for each flood event are provided in **Table 4**.

Table 4 – Mill Creek outfall conditions

Mill/Pringle Recurrence Interval (years)	Willamette River Recurrence Interval (years)	Mill Creek outfall Water Surface Elevation (ft-NGVD29)
2	1.1	122.69
5	1.1	122.69
10	2	127.87
25	5	131.73
50	10	135.07
100	25	137.95

NOTES:

1. The Willamette River drainage area at the Salem USGS gauge is 7,280 square miles. The Mill Creek Basin drainage area is approximately 110 square miles. The main stream to tributary ratio is 66 to 1. The 100 to 1 ratio recommendations in HEC-22 were selected to develop the outfall recurrence intervals.
2. The 2- and 5-year Mill Creek basin recurrence interval outfall conditions were extrapolated from the HEC-22 recommendations.
3. The HEC-22 recommendations assume unregulated river systems. Although the Willamette River is heavily regulated, during the February 1996 event Mill Creek was estimated to be a 90-year peak flow while the Willamette

River had a 25-year peak flow. The 1996 event provides confidence in the HEC-22 methodology for the Mill Creek design outfall.

Quality Assurance Review

Multiple reviews were conducted and documented as part of the Mill Creek Basin model development. QA/QC check sheets are provided in **Appendix 11.C**. The existing conditions 100-year event model has an overall hydraulic continuity error of 0.46% and a runoff continuity of 0.000%, both of which are less than the maximum error of +/- 2% that XP Solutions' documentation recommends (XP Solutions, 2014). Localized instabilities in the stage and/or flow were fixed where needed. All water was captured in the link/node network. The maximum water surface elevation that can be reached at each node without spilling or "smoke stacking" was documented in the node notes within xpstorm, as well as the "MAXWATER" field within the node's GIS attribute table. Channel cross sections where checked for vertical wall extrapolation and modified where necessary to contain all of the flow in the channel. The final cumulative 2-D Mass Error for the 100-year existing conditions model was -0.2%, which is within XP Solutions' documented acceptable range of +/- 1% (XP Solutions, 2014).

Model Calibration/Verification

Historic Streamflow and Stage Records

Streamflow data for the period of interest are available at three active gauges and one inactive gauge in the Mill Creek Basin. Crest Stage Gauge (CSG) data, which provides the maximum water surface elevation for individual events, are available at nine locations in Mill Creek Basin. **Figure 13** shows the location of the streamflow and crest stage gauges for Mill Creek Basin. A summary of the streamflow gauges is as follows:

The Mill Creek 3 (MIC3) streamflow gauge is located on Mill Creek, south of North High School and upstream of a railroad trestle. The elevation of the gauge is 147.96 ft. The contributing drainage area is approximately 115 square miles at the gauge, most of which is located in agricultural areas outside of the City of Salem. The Shelton Ditch diversion, which is located 2.3 miles upstream, significantly reduces the flow in the reach of Mill Creek between the diversion and its outlet into the Willamette River. During the model calibration, MIC3 was primarily used to calibrate the Shelton Ditch weir coefficients. Minor backwater effects can be caused by high stages in the Willamette River, which is located 2 miles downstream of MIC3. Stage records for the gauge were provided in 15-minutes intervals. The period of record for the gauge is from February 2007 to present.

The Mill Creek 12 (MIC12) streamflow gauge is located on Mill Creek, just downstream of Turner Road. The elevation of the gauge is 224.5 ft. The contributing drainage area is approximately 110 square miles at the gauge, most of which is located in agricultural areas outside of the City of Salem. Since MIC12 is located at the upstream extent of the Mill Creek Basin model, the observed flows from the gauge were input into the model as user defined inflows for each of the calibration events. Stage records for the gauge were provided in 15-minutes intervals. The period of record for the gauge is from October 2006 to present.

The Shelton Ditch 3 (SHE3) streamflow gauge is an inactive gauge that was located on Shelton Ditch, just downstream of Winter Street. The elevation of the gauge is 130.32 ft. Stage recordings were provided in 15-minutes intervals. The period of record for the gauge is from November 2012 to July 2014, when it was inactivated due to the Winter Street bridge replacement. While the gauge was not yet functioning during the January 2012 event, various manual streamflow measurements were made at the site during the event. City staff used the streamflow data to construct an approximate flow and stage hydrograph at the location of SHE3 for the event. This gauge was used in tandem with the Mill Creek 3 gauge to calibrated the Shelton Ditch diversion weir coefficients as well as local hydraulic parameters. Stage records for the gauge were provided in 15-minutes intervals.

Along with streamflow and stage gauges, the City of Salem also provided flood photographs and a log of observed flooding that was reported during the calibration and verification events. These records are mapped in

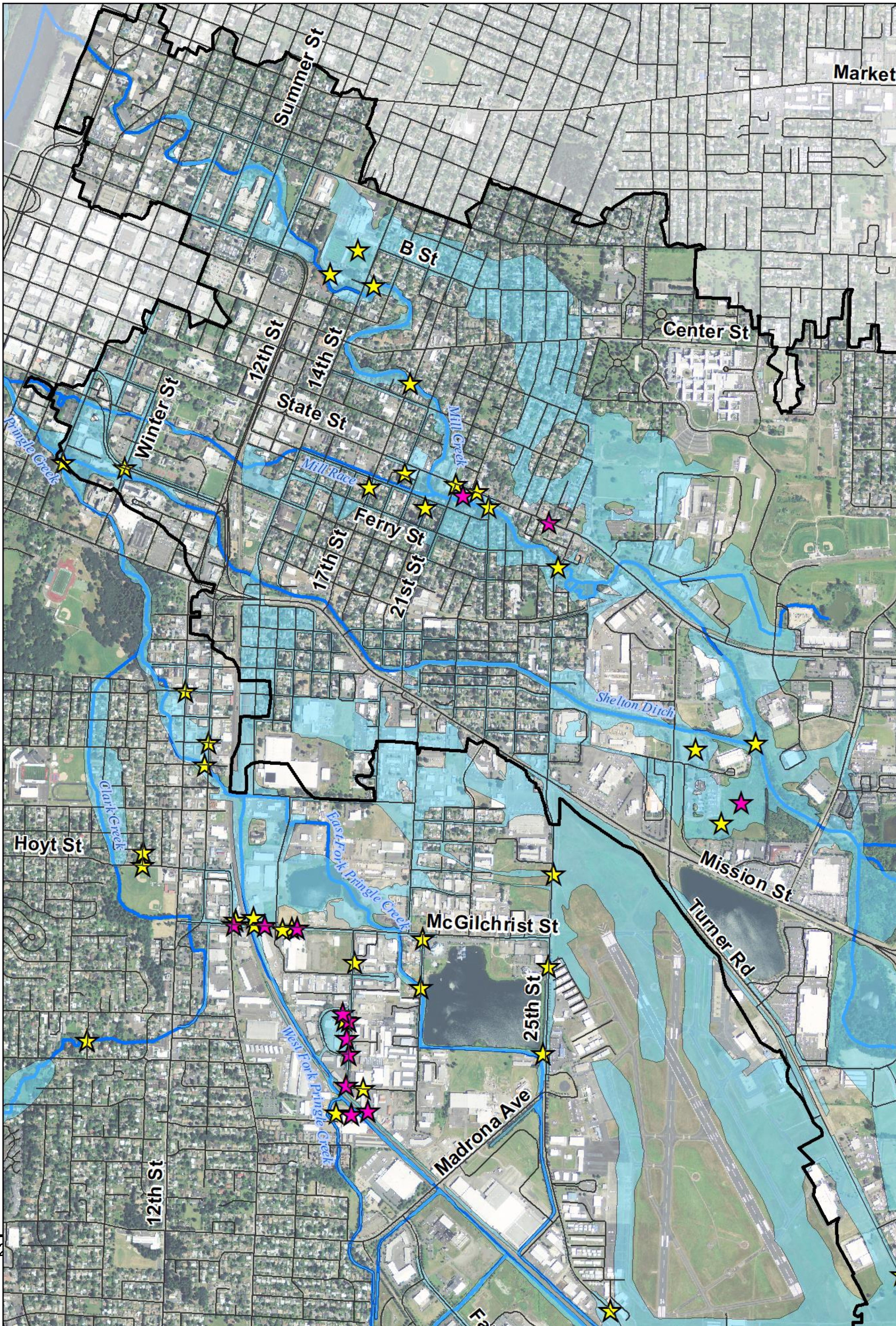

Market
Summer St
B St
Center St
12th St
14th St
State St
Winter St
Pringle Creek
Mill Race
Mill Creek
Ferry St
17th St
21st St
Shelton Ditch
Clark Creek
Hoyt St
East Fork Pringle Creek
Mission St
McGilchrist St
Turner Rd
25th St
West Fork Pringle Creek
Madrona Ave
12th St

Figure 2 for the 1996, 2012, and 2015 flood events.

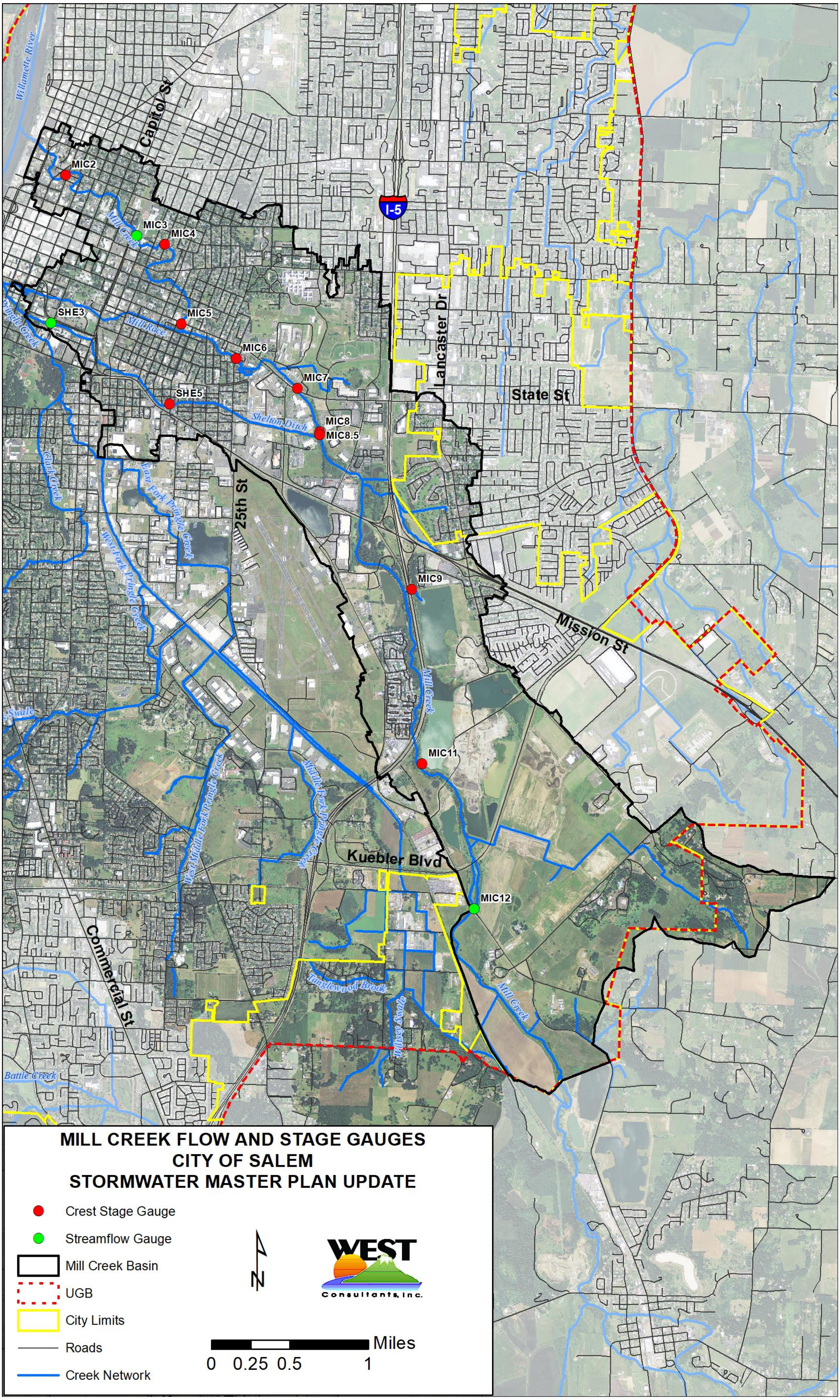


Figure 13 – Streamflow and crest stage gauge locations for Mill Creek Basin

Storm Events

The available streamflow and precipitation data were evaluated in order to select the most appropriate storm events for calibration and verification of the xpstorm model. Because of the relatively short period of record available for the streamflow gauges, the choices for calibration and verification events were limited. The follow events were selected:

<u>January 2012 (Calibration Event #1)</u>

At the McNary Field rainfall gauge the January 2012 storm produced 3.3 inches of rainfall during a 24-hour period, which had an approximate recurrence interval of 10-years. The same event produced 6.1 inches of rainfall during a 48-hour period, which had an approximate recurrence interval of 100-years. During a 72-hour period 7.0 inches of rainfall was measured, which had an approximate recurrence interval of 50-years. This was the largest precipitation event in the City of Salem since 1996 and the largest precipitation event for the period of record for the Mill Creek streamflow gauges. At the MIC12 streamflow gauge, the peak flow was 7,892 cfs, which is between the 25-year and 50-year event. Near the outlets of the Mill Creek Basin, the peak flow measured at the MIC3 gauge was 2,190 cfs and the peak flow measured at SHE3 was 4,658 cfs. Flows in Mill Creek were high enough to overflow into the Pringle Creek Basin at the I-5 overpass at Turner Road. Significant flooding was observed throughout the Mill Creek Basin which makes the January 2012 event ideal for model calibration. It is noted that some snow may have been present in the higher elevations of the Mill Creek Basin. The snowmelt impact was assumed to be minimal and it was not considered in the runoff model.

<u>Early December 2015 (Calibration Event #2)</u>

In early December 2015, a precipitation event produced 2.6 inches of rainfall during a 24-hour period, which had an approximate recurrence interval of 5-years. However, the peak flow at MIC12 was 3,077 cfs, which has a recurrence interval of approximately 2-years. Minor flooding was observed along Mill Creek upstream of Waller Dam. Water levels in Mill Creek were high enough to overflow into the I-5 quarry ponds at the spillway located upstream of I-5. No floodwaters from Mill Creek overflowed into the Pringle Creek Basin. Near the outlet of the Mill Creek Basin, the peak flow measured at the MIC3 gauge was 889 cfs.

<u>Mid December 2015 (Verification Event #1)</u>

In early December 2015, a precipitation event produced 2.6 inches of rainfall during a 24-hour period, which had an approximate recurrence interval of 5-years. The peak flow at MIC12 was 4,346 cfs, which has a recurrence interval of approximately 5-years. Minor flooding was observed along Mill Creek upstream of Waller Dam. Water levels in Mill Creek were high enough to spill into the I-5 quarry ponds at the spillway located upstream of I-5. No floodwaters from Mill Creek overflowed into the Pringle Creek Basin. Near the outlet of the Mill Creek Basin, the peak flow measured at the MIC3 gauge was 1,514 cfs.

Procedures

Initial parameter sensitivity testing indicated that runoff volumes were most sensitive to the initial and critical infiltration rates and that the timing of the hydrograph peak was most sensitive to the subbasin width parameter. Calibration and verification of the Mill Creek Basin xpstorm model was an iterative process. An initial calibration was performed and then tested with the verification events. Parameter adjustments were made and the model was rerun for the calibration event and then retested for the verification events. This process was iteratively repeated until the modeled results satisfactory matched the streamflow observations for the calibration and verification events.

To calibrate the volume, the critical and initial infiltration rates were adjusted in areas that were assigned as silty-clay-loam soils. Silty-clay-loam soils are the dominate soil type in Mill Creek Basin (NRCS, 2014). Initially, these areas were generally assigned critical infiltrations rates of 0.1 inch/hour based on their hydrologic soil classification of "C" as suggested by Musgrave (1955). However, according to Akan (1993), silty-clay-loam soils should have critical infiltration rates in the range of 0.00-0.05 inch/hour. When the critical infiltration rates within that range were used, the model's volume results more closely matched the observations.

The initial infiltration rates were reduced during calibration to represent near saturated conditions resulting in initial infiltration rates that have nearly the same value as the critical infiltration rate. This is considered appropriate since larger flood events in the region generally occur during the colder and wetter winter months when soils are likely to have little time to dry out between storm events.

The initial calibration model produced flashy hydrographs that did not mimic the shape of the hydrographs for the streamflow gauge data. The initial calibration hydrographs had much steeper rising and falling limbs and greater peak flows which suggested that the overland flow travel time to the channel was too quick. Overland flow roughness and channel roughness adjustments had little influence on hydrograph shape. The parameter that had the greatest influence on the hydrograph shape was the subbasin width parameter, which was adjusted accordingly. This resulted in modeled and observed hydrographs that generally matched well for the calibration and verification events.

Gauge stage data, documented reports of flooding, and photos were available for the calibration of the Manning's roughness values for the various stream channels and bridges. Channel roughness values were modified accordingly to best match stage data and observed flooding. When stage data were available near hydraulic structures, entrance/exit loss coefficients, orifice coefficients, and weir coefficients were also adjusted if needed. Observed versus modeled stage and discharge hydrograph plots for the MIC3 and SHE3 streamflow gauges are located in **Appendix 11.D**. Included on each plot is the highest flow or stage ever recorded at the involved gauge. The maximum flow and stage data are included on the plots to provide context for potential uncertainty that may be associated with values of flow or stage that are extrapolated from a limited record of observations.

The Shelton Ditch diversion structures regulate how much flow continues in Mill Creek and how much flow is diverted through Shelton Ditch. The amount of flooding downstream of the diversion structure along Mill Creek and Shelton Ditch is sensitive to the weir coefficients used at the diversion. Significant effort was made to developed a variable weir coefficient that is a function of the stage upstream of the diversion using data from all of the verification and calibration events. Other control structures that were calibrated to match observed conditions include the Mill Race diversion, Waller Dam, and the I-5 quarry pond weir. Initial water surface elevations for ponds during the calibration events were based on either surveyed wintertime water surface elevations or LiDAR (Watershed Concepts, 2009). Since the initial water surface elevations are unknown during the calibration events for modeled ponds and lakes, the assumed water levels are a source of inaccuracy in the calibration.

Existing Conditions Results

The model parameters selected during calibration were used with the 10-, 25-, 50-, and 100-year, 48-hour design storms to develop the peak discharges and water surface elevations for the Mill Creek Basin. **Table 11.E.1** and **Table 11.E.2** in **Appendix 11.E** shows the peak discharges for each link and the maximum water surface elevations for each node located within the UGB for the 10-, 25-, 50-, and 100-year 48-hr design storms, respectively. The 2-D model inundation extents for existing conditions within the Mill Creek Basin area are shown in **Figures 11.E.1** to **11.E.4** in **Appendix 11.E**. **Figures 11.E.5** to **11.E.8** in **Appendix 11.E** categorize the hydraulic conditions at bridges, culverts, and manholes as below the pipe crown elevation, between pipe crown and ground/overflow elevation, or above ground/overflow elevation.

Full Build-Out Conditions

Full build-out conditions for the Mill Creek Basin were estimated and modeled to assist in the development of the basin plan. To develop the full build-out conditions model, the percent impervious values for the existing undeveloped areas and agricultural areas within the UGB were modified according to the land use classifications provided in the July 2015 Salem Area Comprehensive Plan map. The Comprehensive Plan land use classifications were incorporated into the Mill Creek Basin land cover classifications using the category mapping shown in **Table 5.** The percent impervious for each of the subbasins was updated to reflect the full build-out land cover classification. A comparison of the existing condition and full build-out condition percent impervious for the primary subbasins is shown in **Table 6**.

Full build-out conditions were also modeled using the HEC-HMS Flood Warning System model to account for the flow increases upstream of the Mill Creek detailed study area. In the full build-out conditions HEC-HMS model, the impervious areas were modified to account for expected full build-out development in upstream communities including the City of Stayton, the City of Aumsville, the City of Turner, and the City of Salem within Battle Creek Basin. Using the Oregon Zoning feature class that is compiled by the State of Oregon, the existing condition land use directly connected impervious estimates were updated assuming that the “Future Development” zoning areas would be fully developed (DLCD, 2014). The resulting overall existing and full build-out percent directly connected impervious area for the Mill Creek Flood Warning System hydrologic model is 5.3% and 7.4 %, respectively.

Table 5 – Land cover classifications

Comprehensive Plan Classification	SWMP Model Land Cover
Commercial Business District	Developed, Commercial
Commercial	Developed, Commercial
Community Service	Developed, Medium Intensity
Community Service Cemetery	Developed, Open Space
Community Service Education	Developed, Medium Intensity
Community Service Government	Developed, Medium Intensity
Community Service Hospital	Developed, Medium Intensity
Community Service Sewage	Developed, Medium Intensity
Developed, Medium Intensity	Developed, Medium Intensity
Employment Center	Developed, Medium Intensity
Farm Resource Management	Cultivated Crops
Industrial Commercial	Developed, Industrial
Industrial Commercial	Developed, Industrial
Developed, Medium High Intensity	Developed, Medium High Intensity
Mixed Use	Developed, Commercial
Developed, Open Space	Developed, Open Space
River Oriented Mixed Use	Developed, Commercial
Single Family Residential	Developed, Medium Intensity

Table 6 – Existing and full build-out percent impervious area

Primary Subbasin Name	Existing % Impervious	Full Build-Out % Impervious
Mill Creek	22	33
Mill Race	38	38
Shelton Ditch	36	37

Because requirements for detention and the implementation of green infrastructure will be specific to each future development and because the full-build out modeling is for planning purposes, it was assumed that the percentage of connected impervious surface for each land cover type would be similar to current conditions.

Full build-out peak discharges for each link and maximum water surface elevations for each node located within the UGB for the 10-, 25-, 50-, and 100-year 48-hr design storms are provided in **Table 11.E.1** and **Table 11.E.2** in **Appendix 11.E**, respectively. The 2-D model inundation extents for full build-out conditions in the Mill Creek Basin are shown in **Figures 11.E.9** to **11.E.12** in **Appendix 11.E**. **Figures 11.E.13** to **11.E.16** in **Appendix 11.E** categorize the full build-out hydraulic conditions at bridges, culverts, and manholes as below the pipe crown elevation, between the pipe crown and the ground/overflow elevation, or above the ground/overflow elevation.

Under full build-out conditions, the 100-yr, 48-hr design storm peak discharge for Mill Creek is expected to increase by 36 cfs (less than 1%) at the MIC12 streamflow gauge. At the MIC3 streamflow gauge, the 100-yr, 48-hr design storm peak discharge for Mill Creek is expected to have no significant increase. Immediately upstream of the Winter Street bridge, the 100-yr, 48-hr design storm peak discharge for Shelton Ditch's is expected to increase by 7 cfs (less than 1%). The full build-out conditions model for the Mill Creek Basin did not produce significantly higher flows than existing conditions. This is likely because the portion of the Mill Creek Basin that is within the City of Salem is already near full build-out conditions. Also, the communities upstream of Mill Creek represent a relatively small area compared to the total drainage area. As a result, the impacts to the peak flow for Mill Creek were minimal.

ALTERNATIVES ANALYSIS

To develop the list of recommended stormwater capital improvement projects (CIPs) for the Mill Creek Basin Plan, an extensive alternatives analysis was performed using the calibrated xpstorm model. The calibrated existing conditions model results were reviewed and compared with documented flooding observations to develop an initial list of possible operation and maintenance (O&M) and CIP alternatives for Mill Creek Basin. A description of each initial alternative and associated model results is provided in **Appendix 11.F**. Projects evaluated in the alternatives analysis were stormwater pipe replacements, culvert and bridge replacements, control structure modifications, channel vegetation maintenance and debris clearing, detention facilities, flow diversions, floodplain grading, and channel improvements.

After evaluating the initial list of potential Mill Creek Basin alternatives and eliminating projects that did not significantly decrease flood risk in the stormwater model, additional discussions were held between WEST and City staff to further refine the alternatives list. Input from City staff helped eliminates projects that were not feasible due to costs, land ownership, environmental concerns, or planning conflicts.

To mitigate increases in flood risk for areas downstream of certain proposed projects, various combinations of alternatives were evaluated. The selected combinations of conveyance improvement and flood storage alternatives were chosen based on their ability to both lower peak flood elevations in problematic areas and reduce the potential for downstream stage and flow increases. The implementation of the projects should be ordered from downstream to upstream so that the adverse downstream effects of upstream projects are properly mitigated throughout the implementation process.

The first recommended combination of CIPs and O&M projects for the Mill Creek basin (MC-01) includes a stormwater pipe replacement from the Oregon State Hospital to North High School (MC-01a), replacement of the Winter Street bridge over Mill Creek (MC-01b), vegetation management along Mill Creek downstream of North High School (MC-

01c), replacement of the 17th Street bridge over Mill Creek (MC-01d), replacement of Waller Dam with an adjustable crest dam (MC-01e), Vegetation management along Shelton Ditch between 17th Street and Airport Road (MC-01f), and replacing culverts along the ditch located adjacent to Turner Road east of McNary Airport (MC-01g).

The second recommended combination of CIPs for the Mill Creek basin (MC-02) includes the conversion of multiple quarry ponds located adjacent to Mill Creek into three large flood storage areas, the construction of additional levees along Mill Creek, and raising a portion of 37th Ave SE. These projects were not evaluated individually and were not assigned individual designated numbers. It was assumed that all components of this project would be implemented as one project. Since this project involves properties that are not owned or otherwise controlled by the City, significant coordination with the land owners would be expected to occur prior to implementation of this project. The specific locations and extents of the components of Combinations MC-01 and MC-02 are shown in **Figure 14**.

The 2-D model output inundation maps for Combinations MC-01 and MC-02 for existing conditions 10-, 25-, 50-, and 100-year, 48-hr design storms are shown in **Figures 5.G.1** to **5.G.8** in **Appendix 11.G**. Inundation maps for Combinations MC-01 and MC-02 for full build-out conditions 10-, 25-, 50-, and 100-year, 48-hr design storms are shown in **Figures 5.G.9** to **5.G.16** in **Appendix 11.G.**

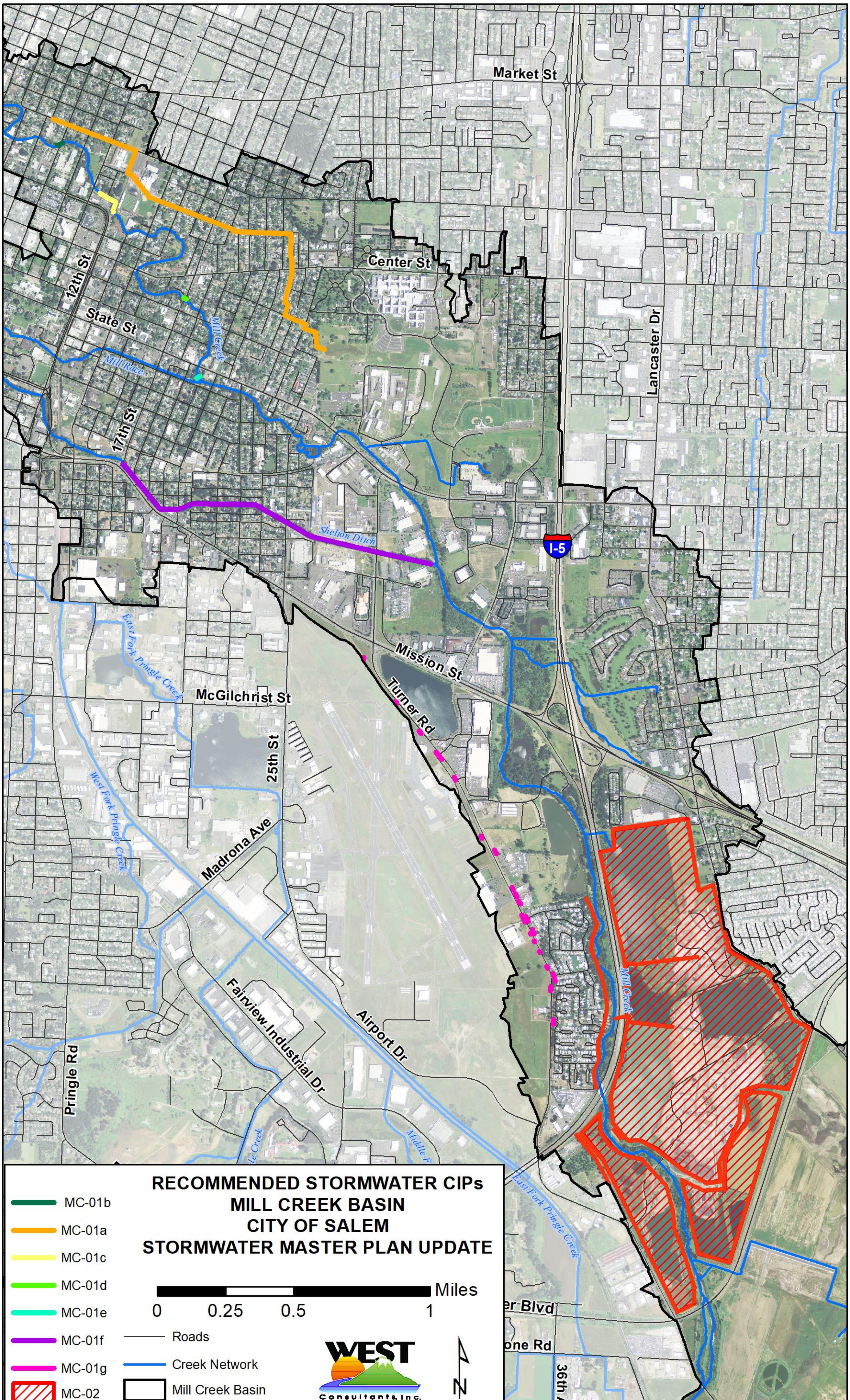


Figure 14 – Project Locations

RECOMMENDED STORMWATER CAPITAL IMPROVEMENT PROJECTS

The recommended stormwater capital improvement projects were divided into three categories, short, intermediate and long-term. Short-term projects are recommended for implementation within the next 5 years. Intermediate-term projects are recommended to be implemented in the next 5 to 10 years. Long-term projects are recommended to be implemented after 10+ years. All cost estimates are in 2018 Dollars.

Short-Term CIPs

The following are the recommended short-term (< 5 years) stormwater CIPs in recommended order of implementation. Detailed cost estimates are provided in **Appendix 11.H**.

Project No. MC-01C - Vegetation management along Mill Creek downstream of North High School

Description: Remove invasive plant species and trim woody vegetation to acceptable limits along 550 feet of Mill Creek downstream of North High School. This project will require the acquisition of a 30-ft wide stormwater maintenance easement along both banks of Mill Creek.

Results: The vegetation management decreases flood risk near North High School for the 10-year food event. For the 100-year event the flood extent decreases near North High but there is also a slight inundation extent increase along Mill Creek, downstream of North High School.

Implementation (Administration, Survey, Design, Permitting):	$1,100
Total Construction:	$5,500
Implementation and Construction Total:	**$6,600**
Design Contingency (40%):	$2,640
Rounded Project Grand Total:	**$10,000**
Easement Acquisition[1]:	$152,000
Grand Total:	**$162,000**
Annual Maintenance Cost:	**$3,333**

[1.] From City of Salem

Project No. MC-01F - Vegetation management along Shelton Ditch between 17th Street and Airport Road

Description: Remove invasive plant species and trim woody vegetation to acceptable limits along 5,500 feet of Shelton Ditch between 12th Street and Airport Road. This project will require the acquisition of a 30-ft wide stormwater maintenance easement along both banks of Shelton Ditch.

Results: Model results indicate a significant decrease of flood risk for the 25-, 50-, and 100-year flood events in the areas adjacent to Shelton Ditch downstream of the Shelton Ditch weir. This included residential areas adjacent to Shelton Ditch, east of 25th Street. The flood risk slightly increased downstream of the project near the Shelton Ditch Winter Street bridge.

Implementation (Administration, Survey, Design, Permitting):	$3,840
Total Construction:	$19,200
Implementation and Construction Total:	**$23,040**
Design Contingency (40%):	$9,216
Rounded Project Grand Total:	**$33,000**
Easement Acquisition[1]:	$1,516,000
Grand Total:	**$1,549,000**
Annual Maintenance Cost:	**$11,000**

1. From City of Salem

Project No. MC-01E - Replace Waller Dam with Adjustable Crest Weir

Description: Replace Waller Dam with a 46-ft long adjustable crest dam.

Results: This alternative was effective at flood risk reduction along State Street and Ferry Street in the vicinity of Waller Dam for flood events with a return period of 25-years or less. For these smaller events, there was a small increase in flood risk for areas located downstream of Court Street.

Implementation (Administration, Survey, Design, Permitting):	$97,095
Total Construction:	$323,650
Implementation and Construction Total:	**$420,745**
Design Contingency (40%):	$168,298
Rounded Project Grand Total:	**$590,000**
Annual Maintenance Cost:	**$3,237**

Project No. MC-01G - Replace Ditch Culverts Along Turner Road East of Airport

Description: Replace 9 culverts with 3-ft circular RCPs and 9 culverts with 4-ft circular RCPs along Turner Road east of McNary Field. The average culvert length is 45-ft.

Results: This alternative helped reduce flooding along Turner Road and some parts of the airport for both the 50- and 100-year flood events.

Implementation (Administration, Survey, Design, Permitting):	$146,658

Total Construction:	$488,859
Implementation and Construction Total:	**$635,516**
Design Contingency (40%):	$254,207
Rounded Project Grand Total:	**$890,000**
Annual Maintenance Cost:	**$4,889**

Intermediate-Term CIPs

The following are the recommended intermediate-term (5-10 years) stormwater CIPs in recommended order of implementation. Detailed cost estimates are provided in **Appendix 11.H**.

Project No. MC-01B - Replace Winter Street Bridge over Mill Creek

Description: Includes the replacement of the Winter Street Bridge over Mill Creek to increase the bridge's hydraulic capacity. Assumed 55-ft span, 75-ft roadway width, and a 4-ft thick bridge deck with no piers.

Results: The bridge replacement significantly lowered flooding extent upstream of Winter Street to North High for the 50- and 100-year flood events. The bridge replacement resulted in a minor reduction in flood risk for the 25-year flood event.

Implementation (Administration, Survey, Design, Permitting):	$596,684
Total Construction:	$1,690,605
Implementation and Construction Total:	**$2,287,289**
Design Contingency (40%):	$914,915
Rounded Project Grand Total:	**$3,203,000**
Annual Maintenance Cost:	**$16,906**

Project No. MC-01D - Replace 17th Street Bridge over Mill Creek

Description: Includes the replacement of the 17^{th} Street Bridge over Mill Creek to increase the bridge's hydraulic capacity. Assumed 80-ft total span, 65-ft roadway width, a 3-ft thick bridge deck, and 3 rows of 1-ft wide piers.

Results: This alternative significantly reduced upstream flooding for the 25-,50-, and 100-year flood events. The bridge replacement also reduced the flood risk in the vicinity of Mill Race by decreasing the floodwaters spilling out of Mill Creek and entering Mill Race at 17th Street. This alternative slightly increased the flood risk along Mill Creek downstream of 17^{th} Street. The Winter Street bridge replacement (Project No. MC-01B) and the vegetation management downstream of North High School (Project No. MC-01C) help offset the additional flood risks downstream of the 17^{th} Street bridge.

Implementation (Administration, Survey, Design, Permitting):	$645,071
Total Construction:	$2,150,235
Implementation and Construction Total:	**$2,795,306**
Design Contingency (40%):	$1,118,122
Rounded Project Total:	**$3,914,000**
Annual Maintenance Cost:	**$21,502**

Long-Term CIPs

The following are the recommended long-term (> 10 years) stormwater CIPs in recommended order of implementation. Detailed cost estimates are provided in **Appendix 11.H**.

Project No. MC-01A - Replace stormwater pipes along B Street and west of State Hospital storage ponds

Description: Includes the replacement of 2,950 linear feet of stormwater pipe along B Street with 5-ft circular RCP and 2,850 linear feet of stormwater pipe downstream of the State Hospital storage pond with 3.5-ft circular RCP.

Results: In the existing conditions model, local flooding start to occur along B Street during the 50-year storm event, and local flooding starts to occur near the State Hospital ponds during the 100-year storm event. Model output indicates a significant reduction in flood risk near B Street between 18th Street and Breys Avenue for both the 50- and 100-year flood events. There was also a significant reduction in flood risk for the residential area located west of Walker Park. However, some areas near the storage pond along 25th will still flood during the 100-year event.

Implementation (Administration, Survey, Design, Permitting):	$563,245
Total Construction:	$3,754,968
Implementation and Construction Total:	**$4,318,213**
Design Contingency (40%):	$1,727,285
Rounded Project Grand Total:	**$6,046,000**
Annual Maintenance Cost:	**$37,550**

Project No. MC-02 - Convert quarry ponds into 3 large flood storage areas, construct control structure for each pond, add levees, raise 37th Ave, and add berm along Lakeside Village and Paradise Park

Description: This project includes the conversion of multiple quarry ponds located adjacent to Mill Creek upstream of I-5 into 3 flood storage areas. The northern storage area is approximately 110 acres and will require the excavation of material down to elevation 195-ft. The middle storage area is approximately 335-acres and will require the excavation of material down to elevation 195-ft. The southern storage area is approximately 62-acres and will require excavation of material down to elevation 215-ft. It is unknown if the material would be removed as part of the existing gravel mining operation prior to project construction or if the excavation will occur as part of the project construction. Since the excavation costs are a significant part of the total project costs, two cost estimates are provided for this project for completeness. One estimate excludes the general excavation and haul costs and one includes these costs.

The northern pond will require the construction of a 1,600-ft long berm along its northern boundary and a 2,500-ft long berm along its western boundary. The middle pond will require the construction of a 700-ft long berm along its western boundary and the blockage of two 8-ft x 4-ft box culverts that connect the existing quarry pond to Mill Creek. The southern pond will require the construction of a 1,700-ft long berm along its north eastern boundary and raising approximately 1,800-ft of 37th Avenue SE between 0 - 3 ft along its western boundary. Each pond will require the construction of outlet structures. Also included in this project is the construction of a 4,000-ft long berm along Mill Creek adjacent to Lakeside Village and Paradise Park.

Results: Model results indicate that this project significantly reduces the risk of overflows into Pringle Creek for the 100-year flood event. For the 10-year storm event, peak flows downstream at the Mission Street Bridge decreased by 24% and the 100-year peak flows decreased by 12%. This project significantly reduces the flood risk for areas adjacent to Mill Creek and Shelton Ditch for the 10-year through the 100-year events.

Cost estimate including general excavation and haul:

Implementation (Administration, Survey, Design, Permitting):	$18,211,313
Total Construction:	$121,408,756
Implementation and Construction Total:	**$139,620,070**
Design Contingency (40%):	$55,848,028
Rounded Project Total:	**$195,469,000**
Property Acquisition[1]:	$4,130,000
Easement Acquisition[2]:	$1,100,000
Grand Total:	**$24,076,000**
Annual Maintenance Cost:	**$1,214,088**

[1.] From Marion County Tax Assessor, [2.] From City of Salem

Cost estimate not including general excavation and haul:

Implementation (Administration, Survey, Design, Permitting):	$1,754,842
Total Construction:	$11,698,947
Implementation and Construction Total:	**$13,453,789**
Design Contingency (40%):	$5,381,515

Rounded Project Total:	**$18,836,000**
Property Acquisition[1]:	$4,130,000
Easement Acquisition[2]:	$1,110,000
Grand Total:	**$24,076,000**
Annual Maintenance Cost:	**$116,989**

1. From Marion County Tax Assessor, 2. From City of Salem

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