August 12, 2016
Project No. 661M 128571

City of Springfield
255 Fifth Street
Springfield, Oregon 97477

Attention: Molly Markarian

Subject: Engineer Report and Narrative for Channel 6 Letter of Map Revision (LOMR)
Springfield, Oregon

Dear Molly:

This reports the detailed hydrologic and hydraulic engineering analysis supporting the application to the Federal Emergency Management Agency (FEMA) for a letter of map revision (LOMR) to convert the update area (mostly Channel 6) floodplain mapping to a detailed study with mapped floodway and with base flood elevations determined. The update area is shown as only an approximate study on the effective flood insurance mapping (**Figure 1**). Except where out-of-channel inundation occurs (about 20 percent of the total modeled length) the proposed inundation area width is narrower than the existing approximate inundation area. The change results from use of better topography based on LiDAR plus surveyed ground cross-sections and a better understanding of backwater from culverts and bridges.

The update area includes Channel 6 from 5th Street downstream (west) to the I-5 Canal, the I-5 Canal from Harlow Road downstream (south) to the Q Street Canal, and then west (from near Fairhaven Street) to the I-5 Freeway.

The engineering analysis included modeling of flows in Channel 6 using the SWMM Version 5.1 computer program by the US Environmental Protection Agency (USEPA, 2014) and the HEC-RAS Version 4.10 computer program by the US Army Corps of Engineers (USACE, 2010). The SWMM modeling was adapted from recent drainage planning work done for the City for this watershed and was used because the small size of the watershed required detailed consideration of flow timing and attenuation. The HEC-RAS model was used for stream hydraulics because it is widely used and accepted for open channel, bridge, and culvert hydraulics. The hydraulic effects of HEC-RAS were reflected in the SWMM modeling, and the resulting flows were modeled in HEC-RAS. Flows decreased going downstream where attenuation in floodplain storage upstream of culverts was

Amec Foster Wheeler Environment & Infrastructure, Inc.
7376 SW Durham Road
Portland, Oregon
USA 97224
Tel+1 (503) 639-3400
Fax+1 (503) 620-7892
www.amecfw.com

significant. The models are discussed separately in the following sections, and files for both models are included with the digital submittal.

Flows were contained within the channel within the update area for about 80 percent of the channel length. This is in part because the stream channels of Channel 6, I-5 Canal, and Q Street Canal are not natural, but were enlarged and straightened as part of earlier drainage improvement projects including by the US Soil Conservation Service (SCS) in the 1960s.

The flows in Channel 6 are unusually low, largely because the watershed ground surface is rather flat with pocket depressions for shallow storage of local runoff, and road crossing culverts and long runs of closed pipe along the main channels and in the lateral storm sewer have restricted flows. For example, the 100-year discharge at the downstream end of Channel 6 is 78 cubic feet per second (cfs). While the drainage area is only 1.35 square miles (mi^2), typical values for an urban area might be 200 to 300 cfs/mi^2. This restriction causes shallow upstream flooding (most out-of-channel inundation is less than 1 foot deep) but also reduces downstream flows. Areas of out-of-channel inundation generally extended beyond the effective, approximate inundation mapping. The locations where out-of-channel storage and flow reductions occur include the following:

- Upstream (east) of Don Street, about 810-ft length of Channel 6 is out of bank, and about 6 acres are inundated during the base flood. Almost all flooding appears confined to Guy Lee Park, where most of one home plus three park buildings are within the inundation area. Some inundation is greater than 1-ft depth in the park plus a small area within Don Street itself. There may be potential for shallow overflow north along Don Street and Hartmann Lane or south along Nancy Avenue (**Figure 2D**).

- Within the manufactured home park between ClearVue St and Laura St, there are two small out-of-bank inundation areas (each about 120 ft of Channel 6 length) of less than 1-ft depth at both private road crossings of Channel 6, and 7 homes are partially within the inundation areas (**Figures 2D** and **2E**).

- Upstream (east) of Laura Street, about 510 ft of overflow occurs across the ground surface west to and across Laura Street with no channel when the 400-ft long pipe surcharges. These surface overflows are less than 1-ft deep except for small pockets above the pipe and a narrow depression south of the pipe from a 1-ft pipe outlet northwest. There are 1 home plus 5 outbuildings entirely within the inundation and 3 homes and 2 outbuildings are partially or mostly within the inundation area (**Figure 2E**).

- East of Pioneer Parkway, a series of culverts and long pipes under Pioneer Parkway (multiple crossings in series) backs flow into the broad, flat upstream area, inundating about 6 acres and 910 ft of Channel 6 length. The inundation area encompasses 3 homes entirely (two are affected by inundation more than 1 ft deep), 1 home mostly, 6 homes partly, and 2 slightly on the edge. The depth of inundation adjacent is more than 1 ft at two homes; the others are less than 1 ft. Inundation is generally less than 1 ft outside of the streets or park areas (**Figure 2F**).

- Inlet to the T-Street long pipe, between the inlet and the recreation (bike) path west of Fifth Street inundates about 350 ft of Channel 6 length and about 1 acre of area during the base flood (1-percent annual exceedance probability [AEP]; 100-year event). The inundation is greater than 1 ft in some areas, and part of 1 home is within an inundation area of less than 1-ft depth. Several homes west of the pipe inlet appear outside the 100-year inundation area but may still be affected by shallow overflow from larger events or if the pipe inlet were blocked by debris (**Figure 2F**).

GEOMETRY DATA

Ground elevations and structure dimensions for the SWMM and HEC-RAS models were developed from a combination of the following:

- LiDAR data obtained from the State of Oregon Department of Geology and Mineral Industries (DOGAMI, 2009);

- Surveys of cross-section and structure elevations and locations by the City of Springfield (Springfield, 2013 and 2016); and

- Field measurements and documentation of structure dimensions and inlet characteristics by Amec Foster Wheeler engineering staff conducted on May 2, 2013 (for Channel 6), September 19, 2013 (for Pioneer Parkway) and on March 25, 2016 (for the downstream Q Street and I-5 Canals).

Data were surveyed in two phases. The City first surveyed Channel 6 as part of prior drainage planning work conducted by Amec Foster Wheeler for the City. Then, for this LOMR, the City surveyed cross-sections and structures along the I-5 and Q Street Canals.

The survey data from the City of Springfield are included in the digital data submittal along with a sealed certification of the data by the licensed professional land surveyor (PLS).

In addition, engineer-sealed field sketches of the stream crossing structures are included in the digital data submittal as part of the MT-2 forms.

HYDROLOGIC ANALYSIS

The update area includes five subwatersheds, and flows were developed specific to each subwatershed as shown in **Figure 3** and as follows:

- Channel 6 upstream of the I-5 Canal (1.35 square miles; mi^2);
- I-5 Canal upstream of the Channel 6 confluence (0.50 mi^2);
- I-5 Canal at the Highway 126 culvert and confluence with Q Street Canal (2.07 mi^2);
- Q Street Canal upstream of the confluence with the I-5 Canal (3.77 mi^2); and
- Q Street Canal at the I-5 culvert and downstream end of update area (6.09 mi^2).

Four FEMA flows were developed: 10-percent annual exceedance probability [AEP] or “10-year”; 2-percent AEP (“50-year”); 1-percent AEP (“100-year”); and 0.2-percent AEP (“500-year”). The floodway profile maintained the same flows as the 1-percent AEP. This is consistent with standard and accepted practice for FEMA floodway analyses. However, the inundation areas upstream, even if they are often shallow (less than 1-ft deep), reduce downstream flows, so reducing the volume of water stored may cause downstream flows and water surface elevations to increase. This effect may be partly or fully offset by providing storage elsewhere for flood water or by enlarging areas of restricted conveyance.

Table 1 lists the peak flows used in the HEC-RAS model for the five profiles. The cross-section locations refer to model inputs and, in general, represent feet upstream of the start of that profile (e.g. the “main” profile along Q Street Canal, I-5 Canal, and Channel 6; the I-5 Canal profile upstream of Channel 6, and the tributary in Guy Lee Park).

Flows for Channel 6 Modeled using SWMM

Channel 6 flows were developed using the SWMM model. SWMM was used because the model already had been developed by Amec Foster Wheeler during prior watershed planning work. Model geometry data were surveyed by the City or were measured during the Amec Foster Wheeler field visits on May 2, 2013 and (for Pioneer Parkway) September 19, 2013. The Channel 6 flows involved a detailed delineation of the Channel 6 watershed, and hydrodynamic analysis of rainfall-runoff and conveyance-attenuation where every pipe greater than 12-inch diameter was modeled. The network as modeled in SWMM is shown in **Figure 4**.

The SWMM model was adjusted for the LOMR work by incorporating culvert entrance and exit losses to better reflect hydraulics as modeled in HEC-RAS, and by adjusting some Manning n-values to reflect updated engineering judgment when the HEC-RAS model was developed. Culvert and long pipe data were a combination of City surveys, Amec Foster Wheeler field measurements (e.g. entrances and bridge thicknesses), and City spatial databases (e.g. for material type in long pipe runs).

The SWMM model flows were based on Soil Conservation Service (SCS) Type 1A 24-hour storms appropriate for the Pacific Northwest.

The SWMM model development is described in greater detail in the Channel 6 Stormwater Master Plan that is included with the digital data submittal (Amec Foster Wheeler, 2014).

Flows for I-5 and Q Street Canals Estimated from Stormwater Master Plan Data

Flows for the I-5 and Q Street Canals were determined from hydraulic data presented in the 2008 Stormwater Facilities Master Plan (SWFMP) for the City of Springfield (URS, 2008). The 2008 SWFMP was produced by URS and utilized the MIKE URBAN hydrologic/hydraulic model for its computations. The output data from the simulations are included in Appendix B of the SWFMP, and include the peak flows for a range of recurrence intervals for each modeled link segment. Based on included figures, the identification of segments of interest could be determined. Output data of segments that contribute flow to the lengths of streams being modeled as a part of this LOMR effort were extracted.

Appendix B of the SWFMP includes peak flows, which were tabulated for the 2-, 5-, 10-, 25-, and 100-year recurrence interval events. To determine the 50- and 500-year flows, as required for the submittal of a LOMR, a logarithmic line was fit to the existing data for each segment. The equation of that line was used to interpolate and extrapolate the peak flows at each modeled segment for the 50- and 500-year recurrence event, respectively. The peak flows were determined at the junction of each influent segment from the MIKE URBAN model with the streams modeled for this LOMR. At each junction, the influent and upstream flows were combined for each flood event for the purposes of determining flow data for the HEC-RAS model.

Peak Flow Coincidence at Junctions

Two internal confluences were modeled as junctions within HEC-RAS (see **Figure 3** for locations):

- The junction within Guy Lee Park where a tributary enters from the southeast. This flow synchronicity was explicitly modeled within the SWMM model and its flows were used for both the entering reaches and the combined downstream reach. The upstream areas are small (well under 1 square mile), and precipitation peaks would be expected to be coincident (subject to routing and attenuation effects as modeled by SWMM).

Table 1. HEC-RAS Flows

Location & XS	Flow by Profile (cfs) 100-Yr	FW	10-Yr	50-Yr	500-Yr	SWMM ID
Q St & I5 Canals: Above Channel 6						
200729	119	119	99	115	145	SWFMP
Guy Lee Park: Park Trib						
100596	30	30	20	28	38	311
Channel 6						
13710	47	47	45	47	49	146
13441	47	47	45	47	47&2	(hand)
13023	47	47	45	47	49	xs 13710
12900	56	56	50	55	63	498
12159	54	54	49	53	59	294
11586	50	50	46	49	50	301
11473	48	48	45	47	48	101
10838	52	52	49	51	54	217
10042	55	55	51	54	61	306
9511	73	73	61	70	84	522
9017	93	93	74	89	111	310
8367	70	70	61	68	79	496
7056	74	74	63	72	84	313
6782	78	78	66	76	90	318
Q St & I5 Canals: Below Channel 6						
5977	199	199	166	192	237	SWFMP
4881	234	234	198	227	278	SWFMP
3142	855	855	721	830	1032	SWFMP
2089	888	888	749	862	1073	SWFMP

Notes:

1. XS is cross-section name in HEC-RAS; usually distance in ft upstream along the profile.
2. FW is Floodway and is the same flow as the 100-Yr; this reflects provision of comparable floodplain storage and no increase in flows from encroachment of out-of-channel storage volume.
3. SWMM ID is the Link ID in SWMM.
4. Flow in T Street pipe (XS 13441) is hand-balanced between plan P03 and P02 in HEC-RAS to account for split between overland flow (multiple cross-sections) and the long pipe.
5. "SWFMP": Non-Channel-6 flows are from City of Springfield 2008 Stormwater Facilities Master Plan hydrologic analysis; they don't have a SWMM ID and were developed using MIKE URBAN.
6. "(hand)" denotes that the 500-year flow in the T-Street culvert long pipe was hand-balanced between pipe- and overflow profiles at the inlet to the long pipe (cross-section 13441): 2 cfs overflow + 47 cfs pipe

- The junction where Channel 6 flows into the I-5 Canal. The Channel 6 flows were modeled in SWMM in detail; the tributary flows were estimated using hydrology data from the City of Springfield SWFMP. The upstream areas are similar, and precipitation peaks would be expected to be coincident (subject to routing and attenuation effects as modeled by SWMM). The Channel 6 flow drops sharply down into the I-5 canal, so junction effects have little influence on Channel 6 backwater.

A third confluence was implicitly modeled within HEC-RAS where the I-5 Canal flows south under Highway 126 and joins with the Q Street Canal. Flows were not modeled for the Q Street Canal upstream of this confluence point, so no junction was modeled. The I-5 and downstream Q Street Canals were modeled as a single reach in HEC-RAS. The flows for the combination of Q Street and I-5 Canals were based on the flows provided in the Springfield SWFMP (Hydrology section) for which peak coincidence was already reflected. The flows in I-5 and Q Street Canals are contained well within their channel, so the approach taken is conservative yet reasonable.

Interplay between SWMM and HEC-RAS Modeling

The SWMM and HEC-RAS modeling involved many iterations of back-and-forth analysis to develop results where SWMM flows were being used consistently in HEC-RAS, while HEC-RAS hydraulic restrictions were being consistently modeled in SWMM. This was needed because SWMM was modeling significant floodplain storage (and peak flow attenuation and reduction) at several locations.

Flows were attenuated from upstream-to-downstream at multiple locations of important floodplain storage. These locations are shown in **Figure 2A-F** and were described at the start of this report.

HYDRAULIC ANALYSIS USING HEC-RAS

Flood elevations were modeled using HEC-RAS Version 4.10. Version 5.0 was publicly released after work began on this project, and the project was not converted because of concern about potential version-change issues.

The HEC-RAS model was developed in typical manner, using ground cross-sections from a combination of LiDAR and survey points (described earlier in this report), and culvert and bridge details from a combination of survey points and field measurements by Amec Foster Wheeler engineers. Manning n-values were set based on field observations of channel vegetation (see backup spreadsheet included with digital data submittal with images and notes regarding roughness and n-value). The flows were modeled in SWMM in tandem with HEC-RAS hydraulics to reflect the important effects of peak flow timing and attenuation for this small-area watershed.

The floodplains were modeled and mapped along the studied waterways of Q Street Canal, I-5 Canal, Channel 6, and in Guy Lee Park. The floodplain mapping does not include potential isolated areas of the upstream or lateral storm drain system where localized flooding occurs and that is generally less than 1-ft depth.

The SWMM and HEC-RAS results were considered consistent when hydraulic grade lines in SWMM were within 0.5 ft of the HEC-RAS water surface elevations; however, the elevations were usually within 0.2 ft. Flow results from SWMM were rounded, and changes within about 1 cubic ft per second (cfs) were not copied to the HEC-RAS input.

The update area is in mostly developed area, so the model cross-sections were fairly closely spaced. Channel 6 had 83 cross-sections along the 7,733 ft modeled. Q Street and the I-5 Canals were larger, more regular sections, and the flow was confined within their deep channels, so cross-section spacing was larger: 26 cross-sections along 6,706 ft (258-ft average spacing). The small tributary in Guy Lee Park was undeveloped, and was just backwater from Channel 6, so only two cross-sections were modeled.

The detailed HEC-RAS model results are listed in **Appendix A** along with profile plots and cross-sections from the model.

The following subsections describe the downstream boundaries, justify the use of junctions within the HEC-RAS model, support the Manning n-values used based on field observations, and remark on some QA/QC issues raised by the CheckRAS computer program or by spatial analysis of model data.

Downstream Water Surface Elevations and Non-Coincidence with Willamette River

The starting downstream water surface elevations were obtained from published backwater elevations for the Willamette River nearby (**Figure 1**). These elevations (and the corresponding HEC-RAS profile numbers) are listed in **Table 2**.

Table 2. Downstream Backwater Elevations

HEC-RAS Profile#	Elevation (ft NAVD88)	Profile (AEP and "Year")
1	424.61	1% AEP; 100-year
2	425.61	1% Floodway; 100-yr Floodway
3	420.01	10%; 10-yr
4	422.81	2%; 50-yr
5	428.81	0.2%; 500-yr

The base floods on the river and on the Channel 6 system would not be coincident because of their greatly different watershed areas and other characteristics (such as elevation). So the Channel 6 profiles were started using normal depth consistent with accepted FEMA practice. The slope of 0.0007 (i.e. 0.07 percent or about 3.7 ft per mile) was used to start all profiles west of the I-5 Freeway and resulted in a profile that was consistent with the overall channel gradient in the Q Street Canal.

One exception was that the floodway profile was not started at normal depth, but at a specified elevation 1-foot higher than the normal-depth elevation that resulted for the 1-percent (100-year) profile. This allowed for potential future surcharge from downstream floodway encroachments that could not have been accounted for just by encroaching the most downstream cross-section.

The HEC-RAS analysis and cross-sections include a short reach downstream of the I-5 freeway in order to establish the downstream boundary and to properly model the I-5 culvert hydraulics. However, the LOMR update boundary is drawn along the I-5 Freeway and does not include the area between the I-5 Freeway and S Garden Way. Areas west of the I-5 Freeway are in the City of Eugene and were not part of the LOMR update area, although cross-sections were included in the hydraulic model of the culvert under the I-5 Freeway. The flood elevations west of the I-5 Freeway were modeled, and the most conservative downstream floodway was estimated for that area; however, results from the HEC-RAS modeling for that reach were submerged by (and thus governed by) backwater from the Willamette River.

MANNING ROUGHNESS N-VALUES

Manning n-values were set by comparing field observations of vegetation and channel condition to published references. This study used the published n-value tabulation for urban streams for the nearby Portland metropolitan area (METRO, 1980). A scan of this summary is included with the digital data submittal.

The n-values were validated by comparing with the guidance for selecting n-values published jointly by the USGS and US Federal Highway Administration (USGS, 1989). The USGS guidance gave too broad a range for vegetation for specific n-values but its ranges were utilized to validate the n-values used for this project.

The waterways modeled in this update are all straight and with no meanders. They appear to have been straightened, channelized and enlarged at some point in the past as part of a drainage improvement project. Manning n-values are lower than for natural streams; however, they are higher than for larger streams or rivers.

Documentation of field photos and n-value notes from our field observations is provided as an annotated spreadsheet file in the digital data submittal.

Table 3 summarizes the n-values used for the HEC-RAS modeling.

Table 3. Manning N-Values for HEC-RAS Modeling

Ground Cover	N-Value
Small Urban Streams, Straightened:	
Clean and lined	0.025
Clean and short / mowed grass on sides	0.03
Clean and no brush either side	0.04
Clean bottom; light brush both sides	0.05
Clean bottom; dense brush both sides (blackberries)	0.07
Dense high weeds throughout	0.08
Willows throughout	0.10
Floodplains:	
Paved	0.02
Lawn / golf course (mowed)	0.03
Pasture / field (long grass)	0.04
Weedy (stiffer weeds)	0.05
Heavy brush (blackberries)	0.07
Forest / trunks inundated	0.10
Forest / branches inundated	0.12
Willows	0.15
Landscaped yards (not lawn)	0.06

Notes:
1. Data from Portland METRO, 1980 Tables.
2. N-values are for straight stream with no meanders; values are higher if stream meanders; values are lower for larger streams.
3. Values consistent with guidance from FHWA and USGS, 1989
4. Values for channel with short grass interpreted from floodplain.

QA/QC Remarks for Review of LOMR Files

Check-RAS Version 2.01 was run as part of the QA/QC process for this model. Those files are included in the digital data submission. A number of remarks are informational only and did not require specific response (e.g. type of flow at bridges and culverts; name of stream). Responses to other comments are included in the Check-RAS report database. In addition, a number of spatial analyses were performed to confirm internal consistency between the model, the floodway data table, and the flood mapping. The following remarks are provided to facilitate review and use of these model results, and relate to both the Check-RAS and spatial analysis checks:

- There are many references to n-values that do not change from floodplain to channel. N-values were established based on field reconnaissance and imagery, with consultation of regional n-value standards and guidance from Federal Highway Administration (FHWA) and

US Geological Survey (USGS) guidance (USGS, 1989). The channels studied all appeared to be engineered, straight, regular shape and surface, so n-values were often low in the channel relative to typical meandering urban streams with dense vegetation. Backup notes and images for the study reaches is provided in an n-value spreadsheet that accompanies the HEC-RAS model in the digital data submission.

- Junctions were used within the HEC-RAS model. This is justified in the discussion earlier in this report.

- Ineffective areas were used in a number of locations apart from structures. These ineffective areas include areas where flow in shallow out-of-channel areas was in eddy areas (e.g. in roadways perpendicular to the channel) or that would not convey flow effectively. This represented a reasonable behavior and avoided underestimating the upstream water surface elevation. Sometimes ineffective areas were within the channel banks, this was considered reasonable behavior given geometry or presence of an upstream pipe outlet that was not modeled (upstream of the study area). Ineffective areas are documented in the “comments” of the HEC-RAS cross-section data where not clearly associated with a structure.

- The cross-sections were rather closely spaced considering how regular the stream channel was, and were located at locations where the survey crews could safely access the waterways. In many cases, cross-sections were located close to the structure inlets or outlets; this was reasonable considering the scale of the study.

- Some locations will have wetted topwidths that appear inconsistent between the HEC-RAS model data and the floodplain mapping. The floodplain extent from the HEC-RAS model was plotted on the map and visually confirmed to be consistent with the map; however, the mapped topwidth does not “subtract” portions of a cross-section that might be ineffective or be “dry” (ground above the water surface). In a few instances, it is not possible to force the floodplain to coincide between the HEC-RAS model and the map, because overflows from culverts just upstream will “spill” or “fall” into the downstream channel on one or the other side of the channel, and HEC-RAS cannot model this effect.

- Reach lengths may flag messages in CheckRAS. Reach lengths were determined by spatial analysis of cross-section lines and reach flow alignment lines that considered locations of out-of-channel flow and bends in the flow. The alignment lines were included as SHP files in the digital data submission (cl-center-ln.shp and cl-leftrt-ln.shp).

FLOODWAY DATA AND ENCROACHMENTS

The floodway was modeled and mapped based on applying a standard 1-ft maximum allowable surcharge using equal conveyance reduction from both sides of the channel.

The base flood (1-percent AEP) flow was contained within the channel for all of the Q Street and I-5 Canal cross-sections. These reaches were modeled with no floodway encroachment in the physical channel, even where the HEC-RAS model channel was less than the physical channel. The floodway stations were thus set to the floodplain boundary in these reaches.

The base flood flow was also contained within the channel for many of the Channel 6 cross-sections. However, the channels along Channel 6 were shallower than for Q Street or I-5 Canals, so a small amount of encroachment (usually up to 1-ft depth) was allowed in some locations, outside of the HEC-RAS channel. Most of the cross-sections where out-of-channel flow occurred had less than 1-ft of depth outside the channel, and these were often encroached to near the channel boundaries.

Floodway Data Table

The floodway data is listed in **Table 4** and is included in digital form with the digital data submittal.

Floodway Mapping and Consistency Checks

The floodway boundary was mapped consistent with the HEC-RAS encroachment stations and is included along with the floodplain boundaries and areas in the digital data submittal. Floodway stations were checked as part of QA/QC and found consistent between the floodway data table, spatial data, and HEC-RAS data.

Floodway Flows and Protection of Out-of-Channel Flood Storage

The peak flows were sensitive to the attenuation caused by floodplain storage upstream of constricted stream crossings. The floodway encroachments would largely eliminate that out-of-channel storage, and the peak flows could increase and cause higher-than-allowed flood elevation surcharges.

This floodway encroachment analysis is based on the expectation that if floodway encroachments were to occur, sufficient out-of-channel flood storage would be preserved (e.g. with cut-and-fill mitigation) or downstream conveyance would be sufficiently expanded to accommodate what would otherwise be an increase in flow without increases in base flood elevation that exceed the 1-foot maximum allowed floodway surcharge.

TABLE 4A: FLOODWAY DATA: Q STREET CANAL

FLOODING SOURCE		FLOODWAY			BASE FLOOD WATER-SURFACE ELEVATION			
CROSS SECTION[1]	DISTANCE[2]	WIDTH (FEET)	SECTION AREA (SQUARE FEET)	MEAN VELOCITY (FEET PER SECOND)	REGULATORY	WITHOUT FLOODWAY (FEET NAVD)	WITH FLOODWAY	INCREASE (FEET)
Q STREET CANAL								
not mapped	-605	62.66	485.91	1.83	424.61 [3]	424.29	425.27	0.98
not mapped	-508	67.17	515.99	1.72	424.61 [3]	424.37	425.32	0.95
not mapped	-473	30.00	285.74	3.11	424.61 [3]	424.34	425.30	0.96
A	8	30.00	280.52	3.17	424.78	424.78	425.78	1.00
B	35	78.48	602.05	1.47	424.97	424.97	425.93	0.96
C	347	77.99	573.23	1.55	425.03	425.03	425.97	0.94
D	942	72.31	458.94	1.93	425.18	425.18	426.07	0.89
E	1,387	75.46	468.72	1.89	425.40	425.40	426.21	0.81
F	1,956	72.16	392.33	2.18	425.74	425.74	426.43	0.69
G	2,440	64.94	310.88	2.75	426.34	426.34	426.84	0.50

[1] Cross section is arbitrary and every model cross-section is lettered; FEMA will change these letters during processing
[2] Distance for Q Street Canal is in feet upstream of I-5 culvert inlet
[3] Regulatory water-surface elevation is influence by backwater from the Willamette River

TABLE 4B: FLOODWAY DATA: I-5 CANAL

FLOODING SOURCE		FLOODWAY			BASE FLOOD WATER-SURFACE ELEVATION			
CROSS SECTION[1]	DISTANCE[2]	WIDTH (FEET)	SECTION AREA (SQUARE FEET)	MEAN VELOCITY (FEET PER SECOND)	REGULATORY	WITHOUT FLOODWAY (FEET NAVD)	WITH FLOODWAY	INCREASE (FEET)
I-5 CANAL								
A	0	11.50	65.56	3.57	426.35	426.35	426.84	0.49
B	34	17.00	101.70	2.30	426.70	426.70	427.12	0.42
C	266	18.70	93.12	2.51	427.11	427.11	427.56	0.45
D	282	26.09	101.26	2.31	427.16	427.16	427.61	0.45
E	716	33.51	125.57	1.86	428.39	428.39	428.56	0.17
F	848	37.29	146.41	1.60	428.63	428.63	428.77	0.14
G	969	36.81	144.34	1.62	428.78	428.78	428.91	0.13
H	1,009	36.50	143.31	1.63	428.84	428.84	428.96	0.12
I	1,249	36.91	142.85	1.64	429.18	429.18	429.27	0.09
J	1,714	33.45	134.29	1.74	429.86	429.86	429.91	0.05
K	2,185	33.35	146.15	1.36	430.40	430.40	430.43	0.03
L	2,551	31.21	121.43	1.64	430.77	430.77	430.80	0.03
M	2,810	32.74	102.28	1.95	431.21	431.21	431.23	0.02
N	2,907	33.67	114.97	1.04	431.26	431.26	431.27	0.01
O	3,198	25.92	89.92	1.32	431.47	431.47	431.49	0.02
P	3,539	26.40	95.16	1.25	431.80	431.80	431.81	0.01

[1] Cross section is arbitrary and every model cross-section is lettered; FEMA will change these letters during processing
[2] Distance for I-5 Canal is in feet upstream of confluence with Q Street Canal

TABLE 4C: FLOODWAY DATA: CHANNEL 6

FLOODING SOURCE		FLOODWAY			BASE FLOOD WATER-SURFACE ELEVATION			
CROSS SECTION[1]	DISTANCE[2]	WIDTH (FEET)	SECTION AREA (SQUARE FEET)	MEAN VELOCITY (FEET PER SECOND)	REGULATORY	WITHOUT FLOODWAY (FEET NAVD)	WITH FLOODWAY	INCREASE (FEET)
CHANNEL 6								
A	55	13.10	15.77	4.95	431.21	431.14	431.16	0.02
B	335	16.38	34.26	2.28	433.34	433.34	433.36	0.02
C	620	15.60	34.78	2.24	433.88	433.88	433.91	0.03
D	653	7.43	19.33	4.04	433.88	433.87	433.91	0.04
E	738	7.42	27.93	2.79	435.07	435.07	435.09	0.02
F	750	19.50	55.65	1.33	435.20	435.20	435.22	0.02
G	877	20.70	58.04	1.27	435.25	435.25	435.27	0.02
H	1,012	23.51	61.48	1.20	435.30	435.30	435.32	0.02
I	1,036	7.72	24.69	2.84	435.30	435.26	435.28	0.02
J	1,082	7.72	31.90	2.19	436.34	436.34	436.36	0.02
K	1,098	24.00	71.62	0.98	436.42	436.42	436.44	0.02
L	1,359	22.40	65.63	1.07	436.47	436.47	436.49	0.02
M	1,684	19.80	55.02	1.27	436.56	436.56	436.58	0.02
N	1,945	23.20	57.61	1.22	436.67	436.67	436.69	0.02
O	1,963	11.57	34.01	2.06	436.67	436.67	436.69	0.02
P	2,028	14.58	60.02	1.17	438.73	438.73	438.87	0.14
Q	2,043	23.83	93.53	0.75	438.75	438.75	438.89	0.14
R	2,128	30.00	115.67	0.61	438.76	438.76	438.90	0.14
S	2,163	30.00	116.72	0.60	438.77	438.77	438.91	0.14
T	2,169	28.20	96.25	0.73	438.77	438.77	438.91	0.14
U	2,184	24.26	86.37	0.81	438.77	438.77	438.91	0.14
V	2,285	25.95	86.92	0.81	438.79	438.79	438.92	0.13
W	2,310	22.64	85.35	0.82	438.79	438.79	438.93	0.14
X	2,323	22.07	80.72	0.87	438.79	438.79	438.93	0.14

[1] Cross section is arbitrary and every model cross-section is lettered; FEMA will change these letters during processing
[2] Discance for Channel 6 is in feet upstream of confluence with I-5 Canal
The workmap includes cross-sections for overflow at T Street that are only for the 500-year; those are not shown for the 100-year or floodway data (13434; 13393; 13281; 13166; 13040)

TABLE 4C: FLOODWAY DATA: CHANNEL 6 (CONTINUED)

FLOODING SOURCE	FLOODWAY	BASE FLOOD

					WATER-SURFACE ELEVATION			
CROSS SECTION[1]	DISTANCE[2]	WIDTH (FEET)	SECTION AREA (SQUARE FEET)	MEAN VELOCITY (FEET PER SECOND)	REGULATORY	WITHOUT FLOODWAY (FEET NAVD)	WITH FLOODWAY	INCREASE (FEET)
CHANNEL 6 (Continued)								
Y	2,683	23.96	73.89	1.26	438.90	438.90	439.09	0.19
Z	2,737	20.31	64.92	1.43	438.92	438.92	439.10	0.18
AA	2,973	19.30	65.94	1.41	438.96	438.96	439.19	0.23
AB	2,996	12.71	55.73	1.31	438.97	438.97	439.20	0.23
AC	3,094	12.18	55.75	1.31	439.19	439.19	439.43	0.24
AD	3,110	20.46	69.34	1.05	439.21	439.21	439.45	0.24
AE	3,243	20.80	66.65	1.10	439.25	439.25	439.48	0.23
AF	3,378	19.80	52.07	1.40	439.29	439.29	439.51	0.22
AG	3,415	12.35	34.71	2.10	439.29	439.29	439.51	0.22
AH	3,455	21.52	67.26	1.09	440.58	440.58	441.01	0.43
AI	3,467	24.27	89.52	0.82	440.59	440.59	441.02	0.43
AJ	3,565	22.63	88.59	0.62	440.60	440.60	441.03	0.43
AK	3,757	20.88	69.93	0.79	440.61	440.61	441.03	0.42
AL	3,770	20.92	72.23	0.76	440.61	440.61	441.03	0.42
AM	3,876	20.98	78.64	0.70	440.62	440.62	441.04	0.42
AN	3,998	21.77	70.94	0.78	440.63	440.63	441.05	0.42
AO	4,018	23.29	71.42	0.73	440.63	440.63	441.05	0.42
AP	4,068	16.66	64.65	0.80	440.96	440.96	441.26	0.30
AQ	4,078	17.58	61.48	0.85	440.96	440.96	441.26	0.30
AR	4,177	20.09	68.67	0.76	440.97	440.97	441.27	0.30
AS	4,423	17.97	43.11	1.21	440.99	440.99	441.28	0.29
AT	4,446	16.84	42.40	1.23	441.00	441.00	441.29	0.29
AU	4,563	15.30	39.63	1.31	441.03	441.03	441.31	0.28
AV	4,794	10.57	16.79	3.10	441.11	441.11	441.38	0.27
AW	4,816	4.57	9.85	4.87	441.24	441.24	441.43	0.19
AX	5,242	20.10	46.69	1.03	444.28	444.28	444.35	0.07
AY	5,282	4.00	15.96	3.01	444.28	444.24	444.33	0.09
AZ	5,429	4.00	19.13	2.51	445.58	445.58	445.67	0.09
BA	5,443	30.94	96.56	0.52	445.71	445.71	445.80	0.09
BB	5,448	8.00	37.54	1.33	445.71	445.70	445.79	0.09
BC	5,526	6.00	34.67	1.44	446.47	446.47	446.56	0.09
BD	5,542	32.37	109.80	0.46	446.51	446.51	446.60	0.09
BE	5,585	27.43	97.16	0.56	446.51	446.51	446.60	0.09
BF	5,614	22.91	85.25	0.63	446.51	446.51	446.60	0.09
BG	5,703	21.30	87.23	0.62	446.51	446.51	446.61	0.10
BH	5,717	21.96	91.95	0.59	446.51	446.51	446.61	0.10
BI	5,885	21.88	88.50	0.61	446.51	446.51	446.62	0.11
BJ	6,000	41.57	111.87	0.48	446.52	446.52	446.63	0.11
BK	6,077	29.07	88.52	0.61	446.52	446.52	446.64	0.12
BL	6,102	21.34	78.23	0.69	446.52	446.52	446.67	0.15
BM	6,115	19.26	76.58	0.71	446.52	446.52	446.67	0.15
BN	6,341	22.98	83.60	0.67	446.53	446.53	446.69	0.16
BO	6,560	19.32	64.46	0.87	446.55	446.55	446.71	0.16
BP	6,757	22.70	73.66	0.76	446.59	446.59	446.75	0.16
BQ	6,776	4.40	20.32	2.76	446.59	446.54	446.70	0.16
BR	6,856	5.20	28.43	1.97	447.41	447.41	447.57	0.16
BS	6,869	24.60	88.63	0.53	447.49	447.49	447.65	0.16
BT	6,959	25.68	95.68	0.49	447.49	447.49	447.65	0.16
BU	6,979	23.69	77.15	0.61	447.49	447.49	447.65	0.16
BV	7,397	19.01	89.67	0.52	448.66	448.61	448.77	0.16
BW	7,415	20.67	92.21	0.51	448.66	448.61	448.77	0.16
BX	7,534	35.40	109.05	0.43	448.66	448.61	448.77	0.16
BY	7,644	23.86	91.82	0.51	448.66	448.62	448.78	0.16
BZ	7,666	8.00	48.62	0.97	448.66	448.61	448.77	0.16

[1] Cross section is arbitrary and every model cross-section is lettered; FEMA will change these letters during processing
[2] Discance for Channel 6 is in feet upstream of confluence with I-5 Canal
The workmap includes cross-sections for overflow at T Street that are only for the 500-year; those are not shown for the 100-year or floodway data (13434; 13393; 13281; 13166; 13040)

MAP AND PROFILE CONCURRENCE WITH EFFECTIVE FLOOD INSURANCE STUDY

This study was a conversion of an approximate study to a detailed study, so there were no upstream profiles with which to achieve concurrence. Downstream profile concurrence was automatically achieved by allowing the backwater elevations for the Willamette River to inundate the HEC-RAS profiles while starting the profiles at normal-depth slope.

Map concurrence was also easily achieved. The downstream point of concurrence was at the culvert crossing of Q Street Canal under the I-5 Freeway, where the 100- and 500-year flows are both contained within the culvert. This meant the floodplain boundaries east and west of the freeway do not connect, so the east boundaries were simply replaced with the new LOMR boundaries.

Map concurrence was similar for the upstream end of I-5 Canal at the outlet of the pipe system from Harlow Road and for the upstream end of the LOMR reach of Channel 6. At both locations, the 100- and 500-year flows are contained within the pipe system or culvert, respectively, and the effective “A”-zone approximate flood boundaries are disconnected, so the LOMR update simply replaced the effective boundaries without having to “touch” any upstream boundaries.

The only point where map adjustment was required in order to achieve map concurrence was on Q Street Canal east of the outlet from I-5 Canal under the Highway 126 culvert, where a small polygon of “A”-zone approximate boundary was stretched to connect the detailed flood study boundary to the effective “A”-zone boundary at the LOMR update boundary. These four map concurrence locations are illustrated in **Figure 5**.

DIGITAL WORKMAP AND CERTIFICATION SUBMITTAL

The HEC-RAS spatial input (cross-section and reach locations and overbank flow alignment lines) and results (1- and 0.2-percent AEP floodplain and floodway boundaries) are combined with other input data on a digital workmap. This digital workmap (WORKMAP.DWG) is included along with a digital workmap certification with the digital data submittal.

The floodway was modeled and mapped based on applying a standard 1-ft maximum allowable surcharge using equal conveyance reduction from both sides of the channel.

LIMITATIONS

This report was prepared exclusively for the City of Springfield (the City) by Amec Foster Wheeler Environment & Infrastructure, Inc. (Amec Foster Wheeler). The quality of information, conclusions, and estimates contained herein is consistent with the level of effort involved in Amec Foster Wheeler services and based on: i) information available at the time of preparation, ii) data supplied by outside sources, and iii) the assumptions, conditions, and qualifications set forth in this report. This report is intended to be used by the City for the FEMA LOMR application only, subject to the terms and conditions of its contract with Amec Foster Wheeler. Any other use of, or reliance on, this report by any third party is at that party's sole risk.

Amec Foster Wheeler
Environment & Infrastructure, Inc.

Seth Jelen, PE, CFM, CWRE
Principal Engineer – Water Resources

Reviewed by:

Habib Matin, PE, PhD
Principal Engineer – Water Resources

Attachments: Digital Data Submittal

SJ/

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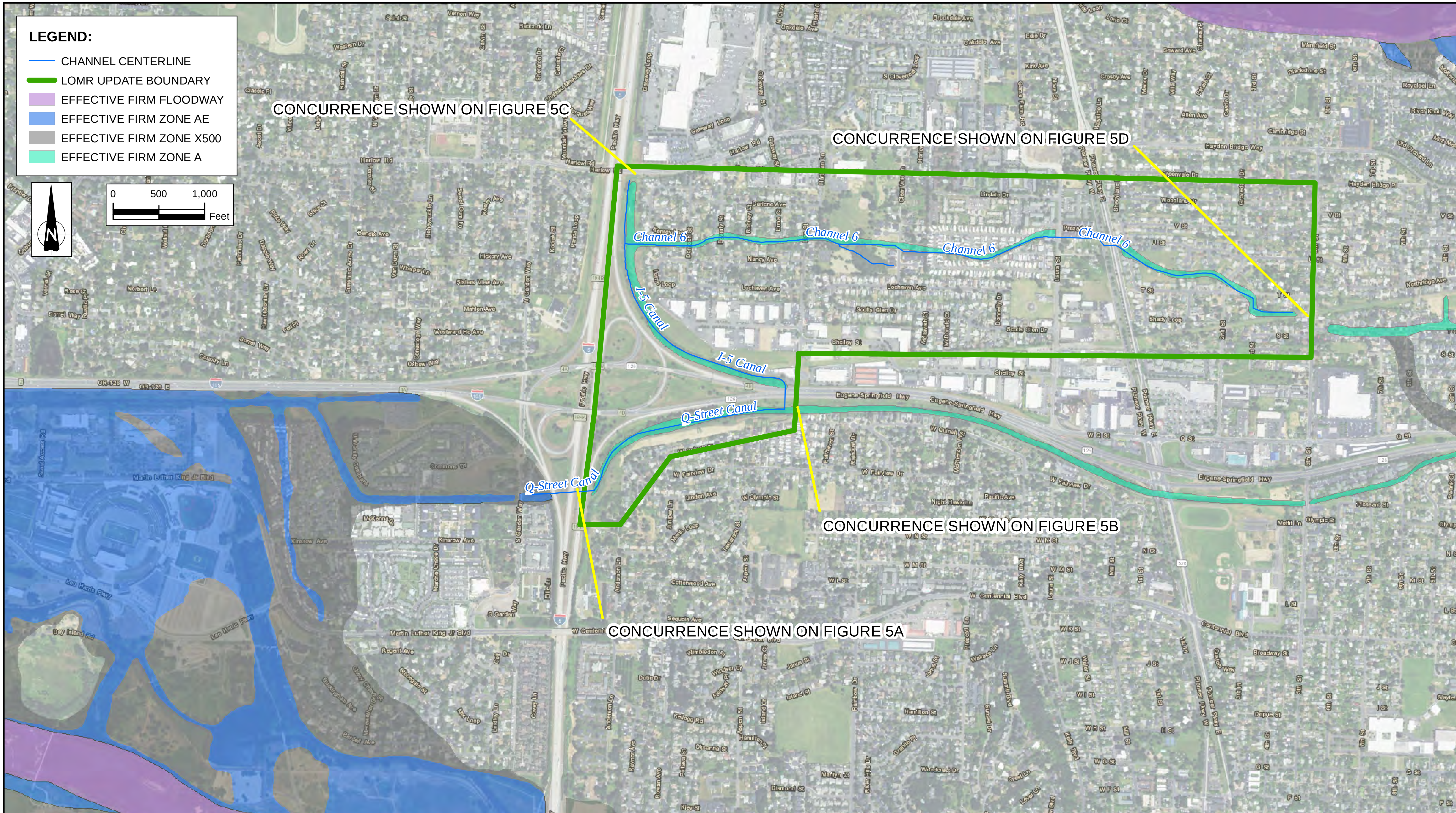
ATTACHMENTS



CITY OF SPRINGFIELD	CHANNEL 6 FIRM UPDATE	DATE JULY 2016
		SCALE 1 " = 1,000 '
Amec Foster Wheeler Environment & Infrastructure, Inc. 7376 S.W. Durham Road Portland, OR 97224	FIGURE 1 - EFFECTIVE FIRM DATA	PROJECT NO. 6-61M-128571
		FIGURE 1

amec foster wheeler

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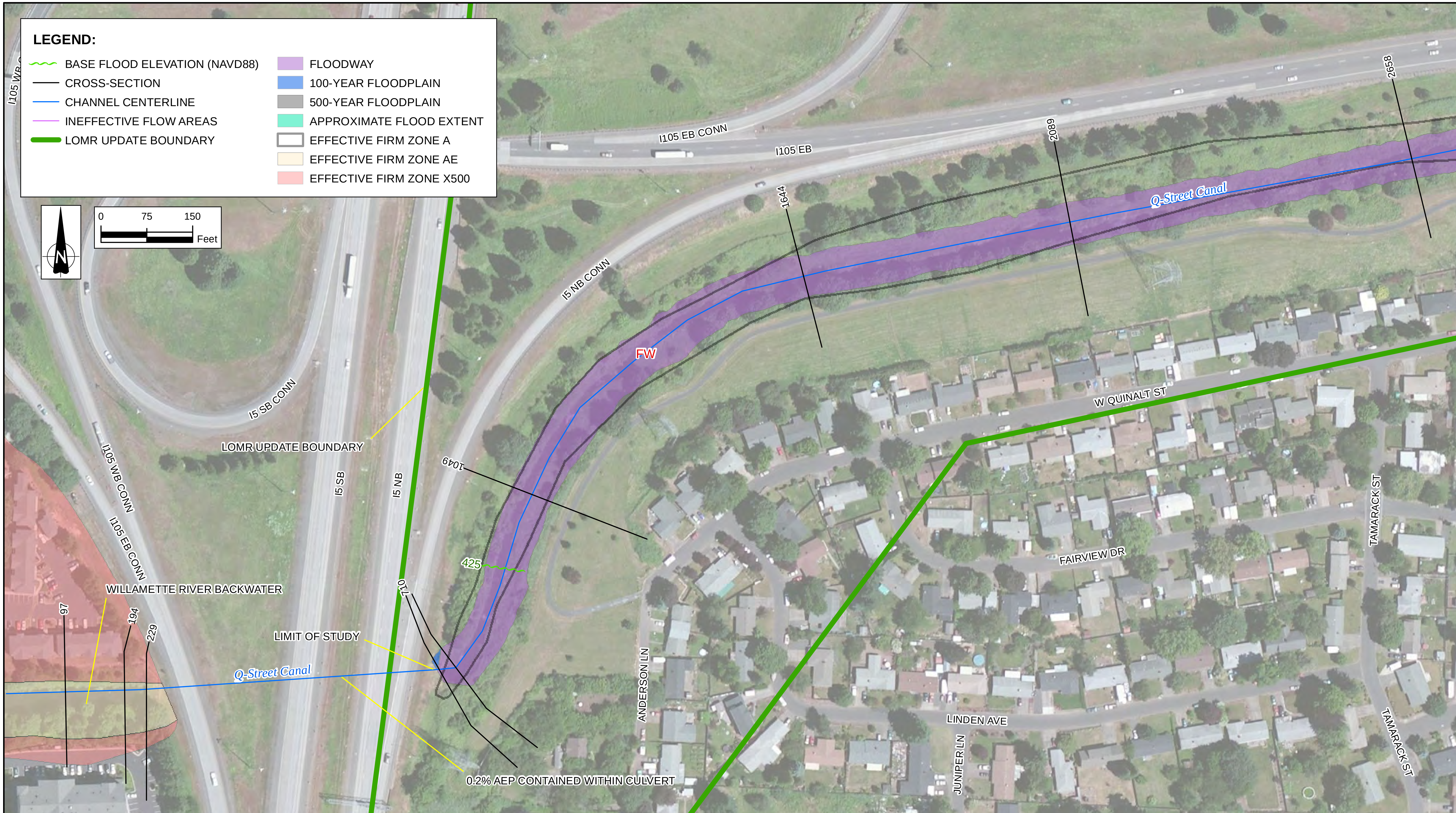

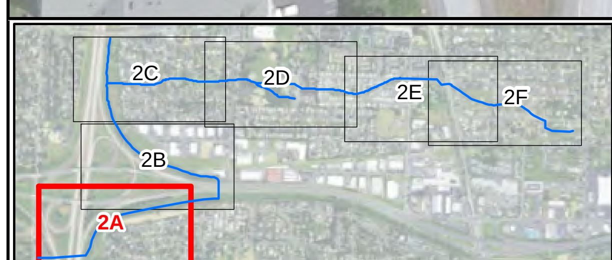

NOTE:
- BFE ELEVATIONS SHOWN ARE WITHIN 0.5 FT.

CITY OF SPRINGFIELD

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Portland, OR 97224

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CHANNEL 6 FIRM UPDATE

FIGURE 2A - REVISED FLOOD EXTENT

DATE	JULY 2016
SCALE	1 " = 150 '
PROJECT NO.	6-61M-128571
FIGURE	2A

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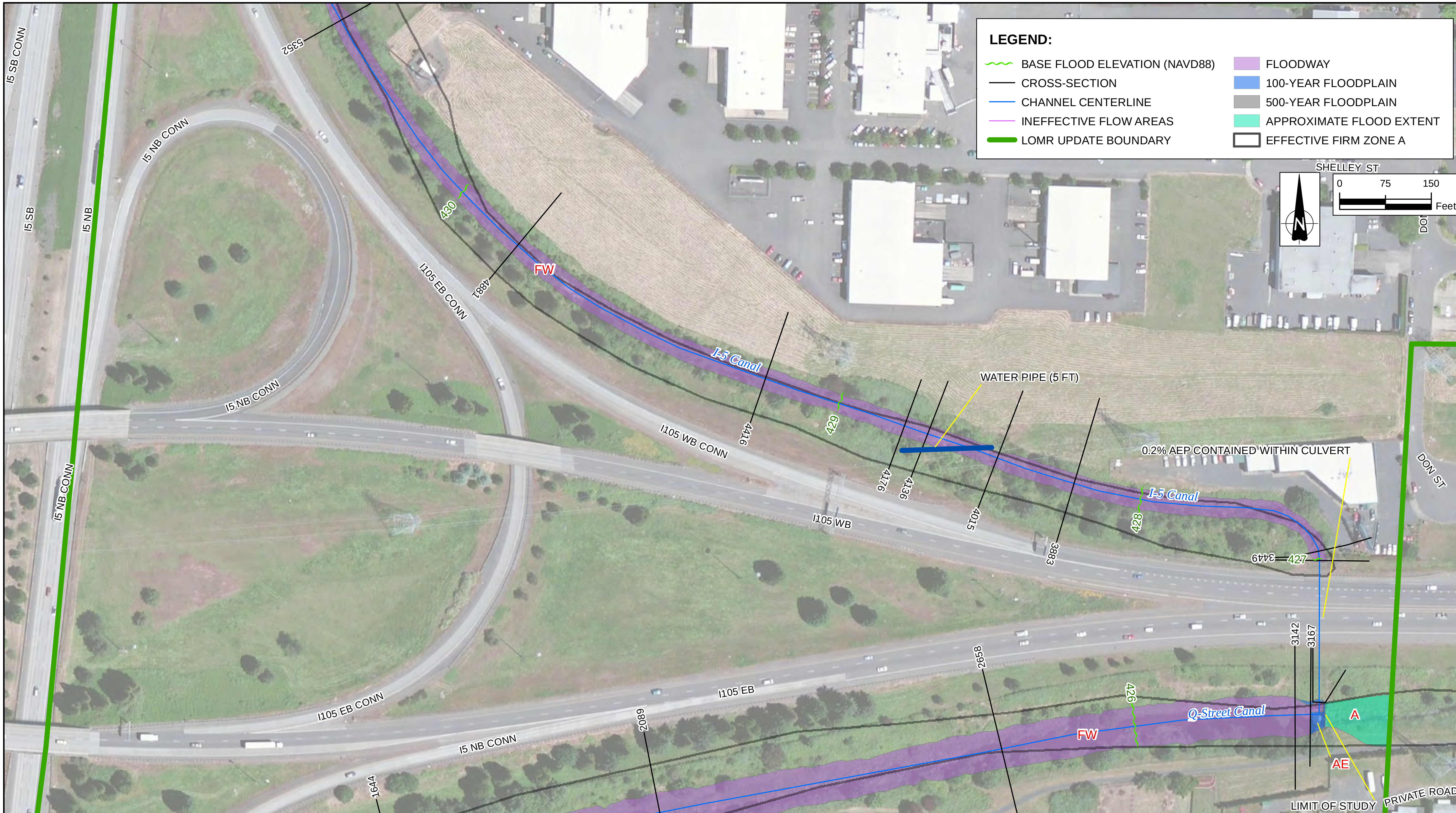

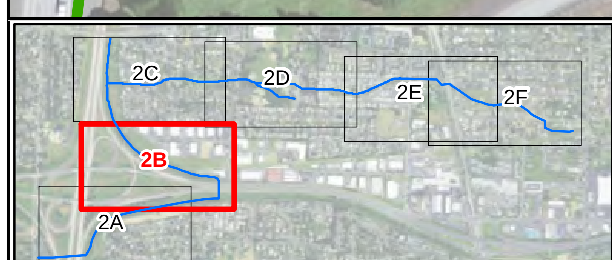

NOTE:
- BFE ELEVATIONS SHOWN ARE WITHIN 0.5 FT.

CITY OF SPRINGFIELD

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CHANNEL 6 FIRM UPDATE

FIGURE 2B - REVISED FLOOD EXTENT

DATE: JULY 2016

SCALE: 1 " = 150 '

PROJECT NO.: 6-61M-128571

FIGURE: 2B

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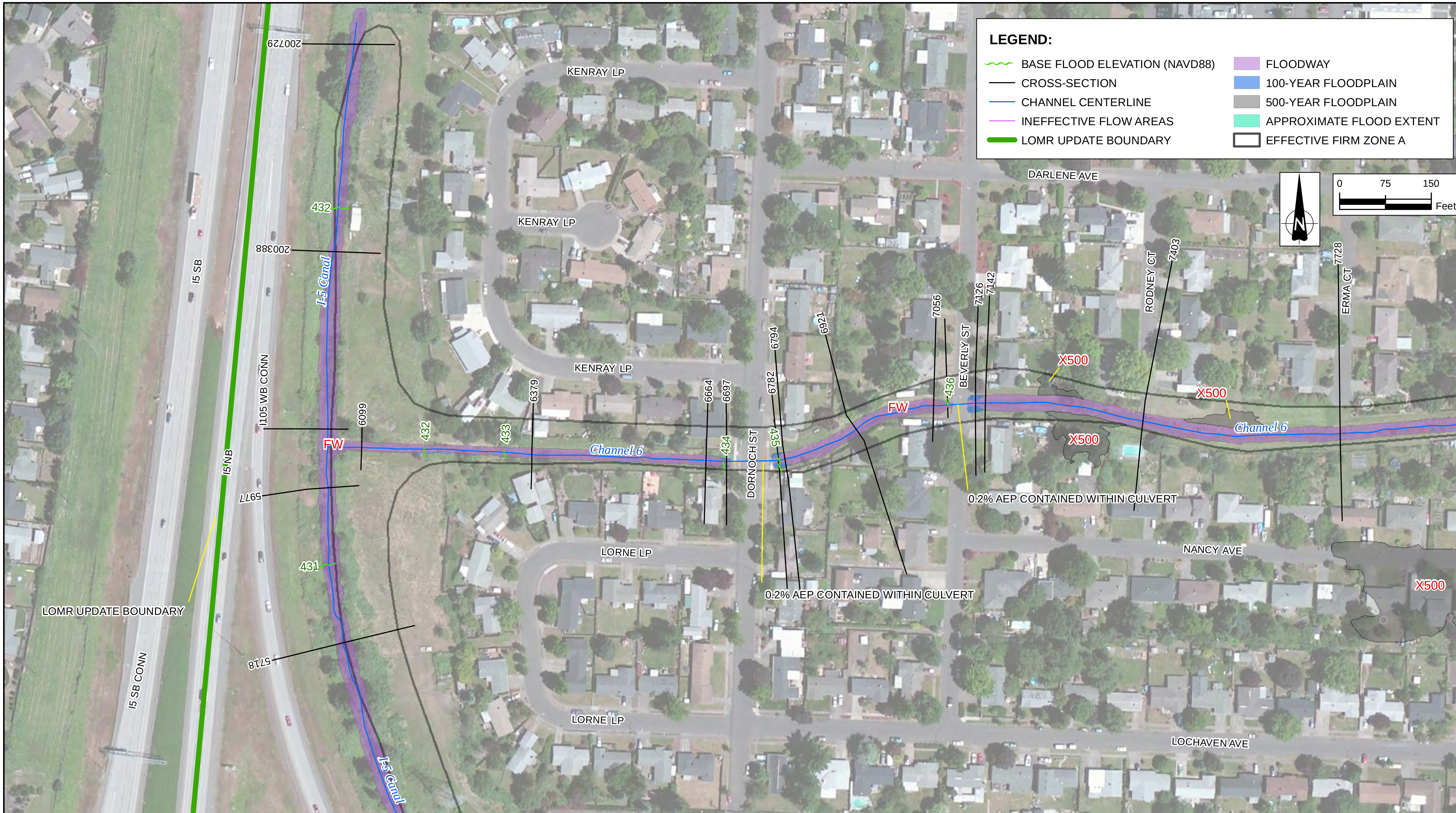

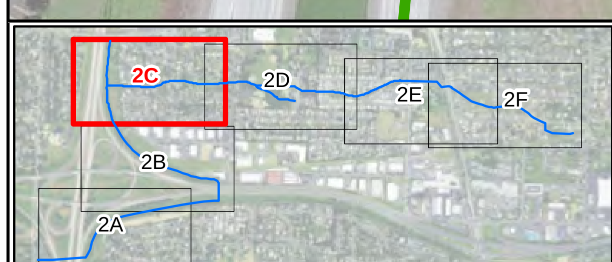

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NOTE:
- BFE ELEVATIONS SHOWN ARE WITHIN 0.5 FT.

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CHANNEL 6 FIRM UPDATE

FIGURE 2C - REVISED FLOOD EXTENT

DATE	JULY 2016
SCALE	1 " = 150 '
PROJECT NO.	6-61M-128571
FIGURE	2C

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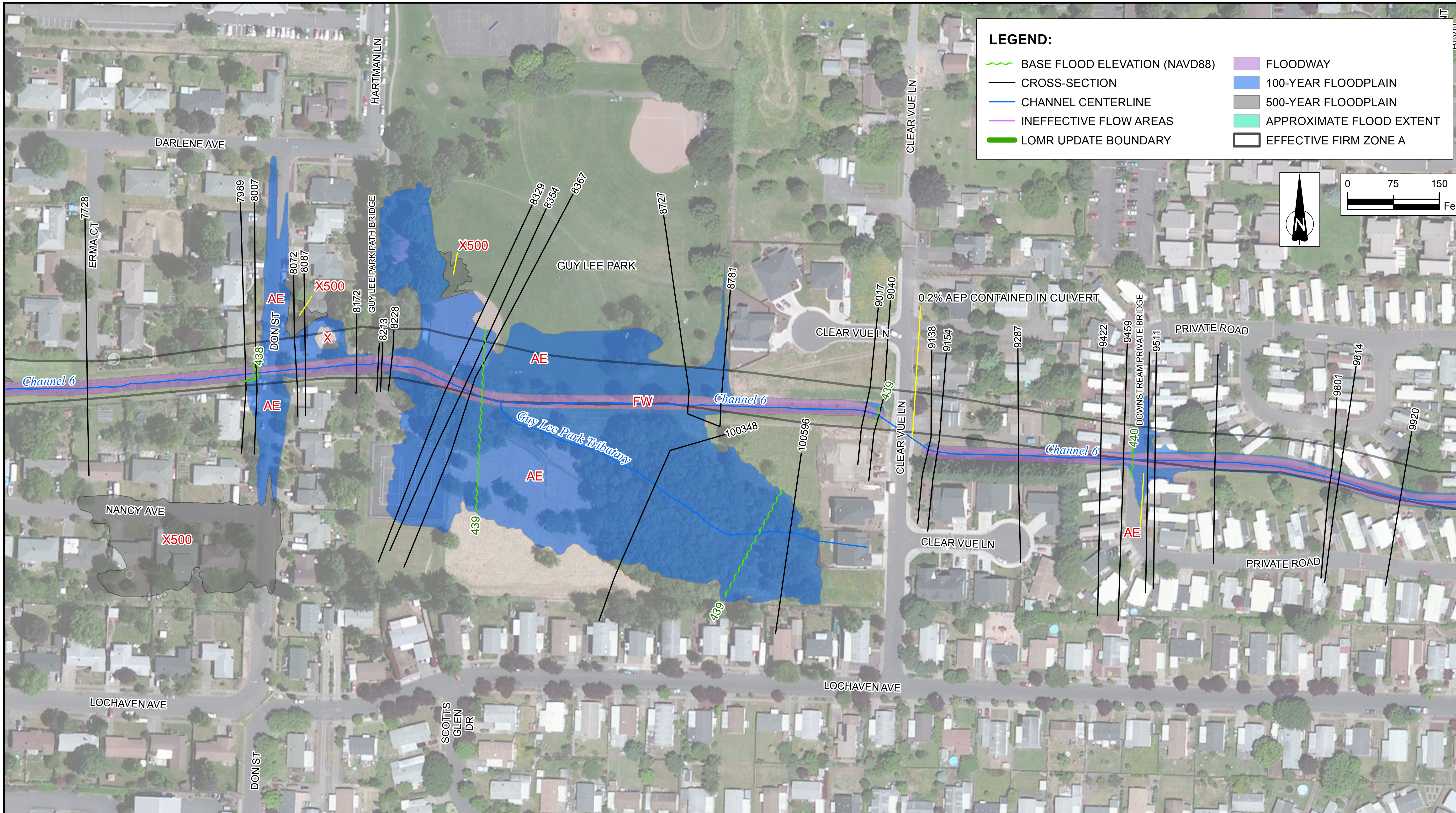

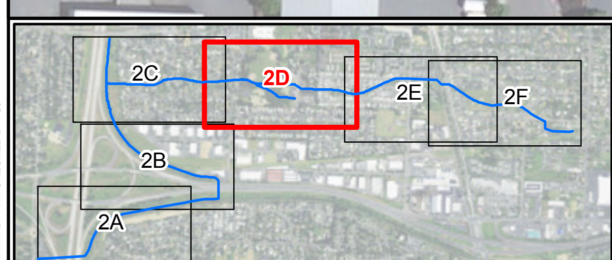

NOTE:
- BFE ELEVATIONS SHOWN ARE WITHIN 0.5 FT.

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CHANNEL 6 FIRM UPDATE

FIGURE 2D - REVISED FLOOD EXTENT

DATE: AUGUST 2016
SCALE: 1 " = 150 '
PROJECT NO.: 6-61M-128571
FIGURE: 2D

DRAWN BY: TM CHECKED BY: SJ

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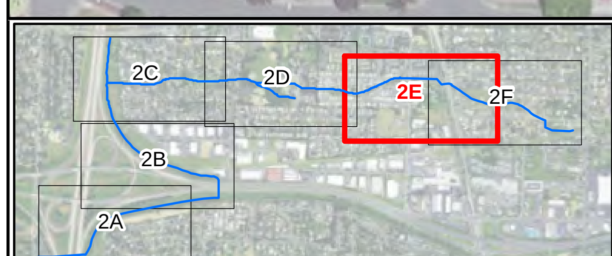

NOTE:
- BFE ELEVATIONS SHOWN ARE WITHIN 0.5 FT.

CITY OF SPRINGFIELD

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CHANNEL 6 FIRM UPDATE

FIGURE 2E - REVISED FLOOD EXTENT

DATE	JULY 2016
SCALE	1 " = 150 '
PROJECT NO.	6-61M-128571
FIGURE	2E

DRAWN BY: TM CHECKED BY: SJ

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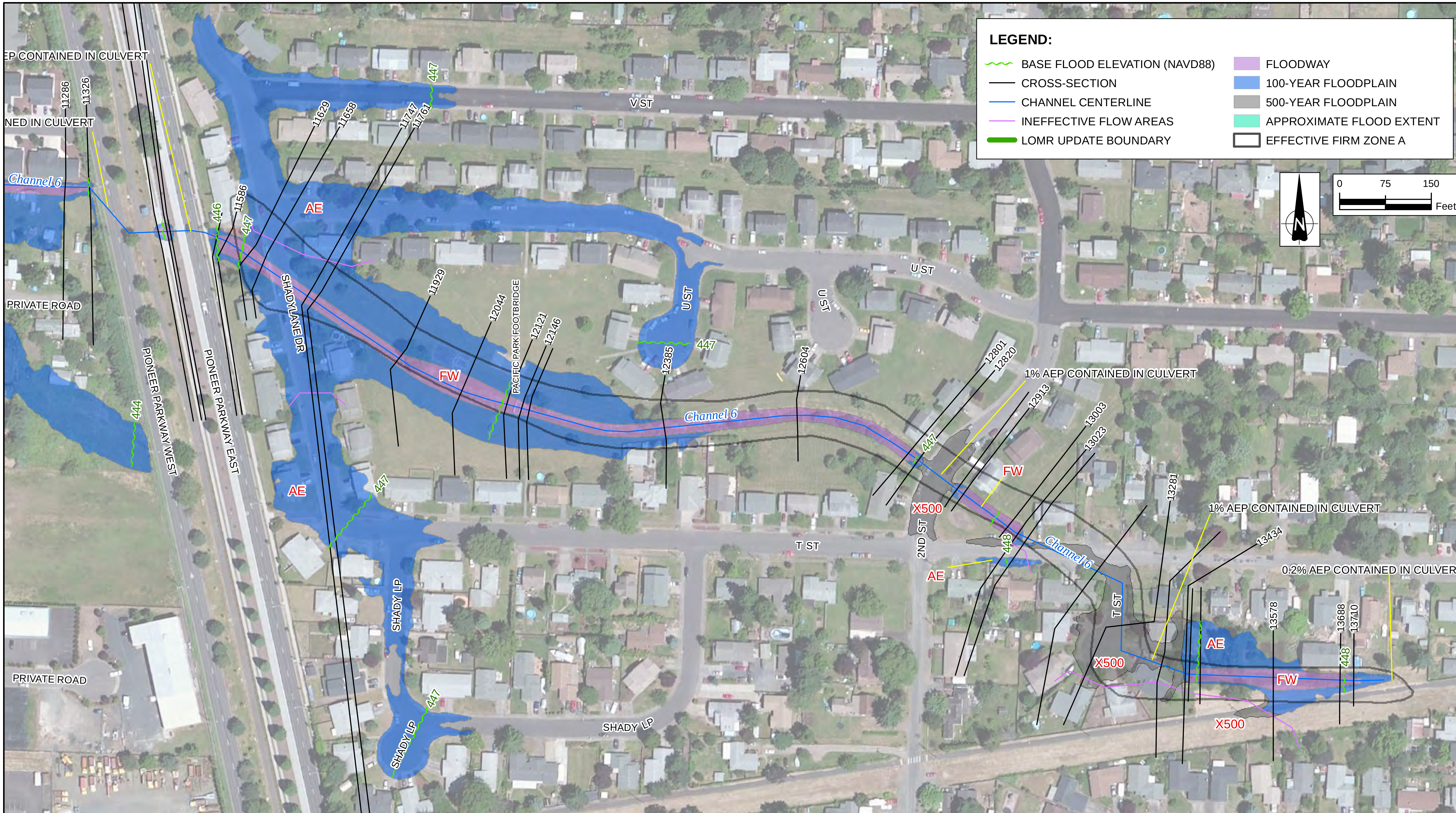
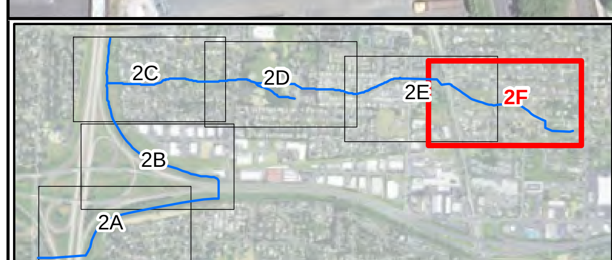


NOTE:
- BFE ELEVATIONS SHOWN ARE WITHIN 0.5 FT.



CITY OF SPRINGFIELD

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7376 S.W. Durham Road
Portland, OR 97224

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CHANNEL 6 FIRM UPDATE

FIGURE 2F - REVISED FLOOD EXTENT

DATE	JULY 2016
SCALE	1 " = 150 '
PROJECT NO.	6-61M-128571
FIGURE	2F

DRAWN BY: TM CHECKED BY: SJ

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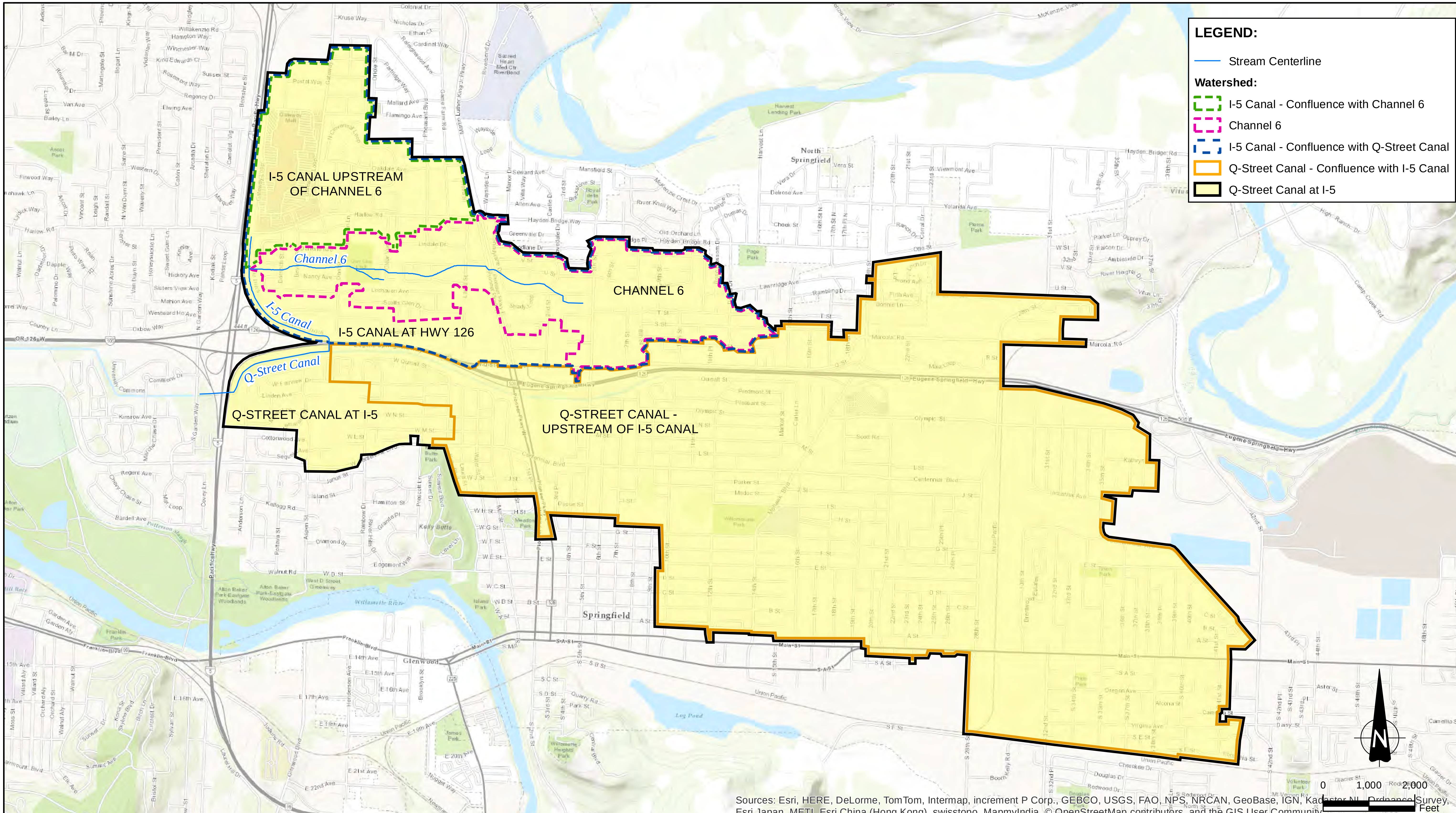

CITY OF SPRINGFIELD	amec foster wheeler	CHANNEL 6 FIRM UPDATE	DATE JULY 2016
			SCALE 1 " = 2,000 '
Amec Foster Wheeler Environment & Infrastructure, Inc. 7376 S.W. Durham Road Portland, OR 97224		FIGURE 3 - SUB-WATERSHED DELINEATION	PROJECT NO. 6-61M-128571
			FIGURE 3

DRAWN BY: TM CHECKED BY: SJ

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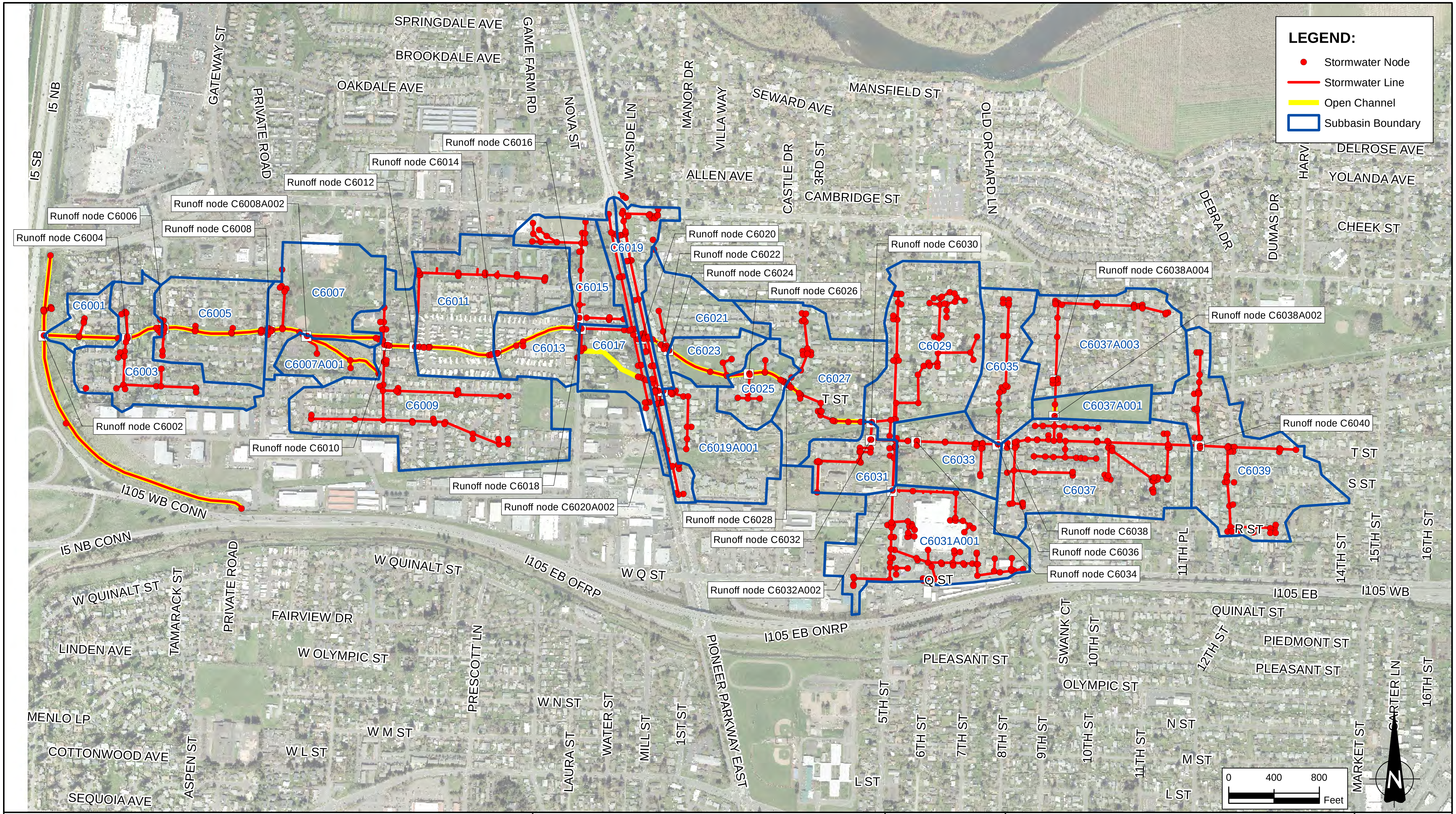

CITY OF SPRINGFIELD		CHANNEL 6 FIRM UPDATE	DATE JULY 2016
			SCALE 1 " = 800 '
Amec Foster Wheeler Environment & Infrastructure, Inc. 7376 S.W. Durham Road Portland, OR 97224	amec foster wheeler	FIGURE 4 - CHANNEL 6 SWMM MODEL GEOMETRY	PROJECT NO. 6-61M-128571
			FIGURE 4

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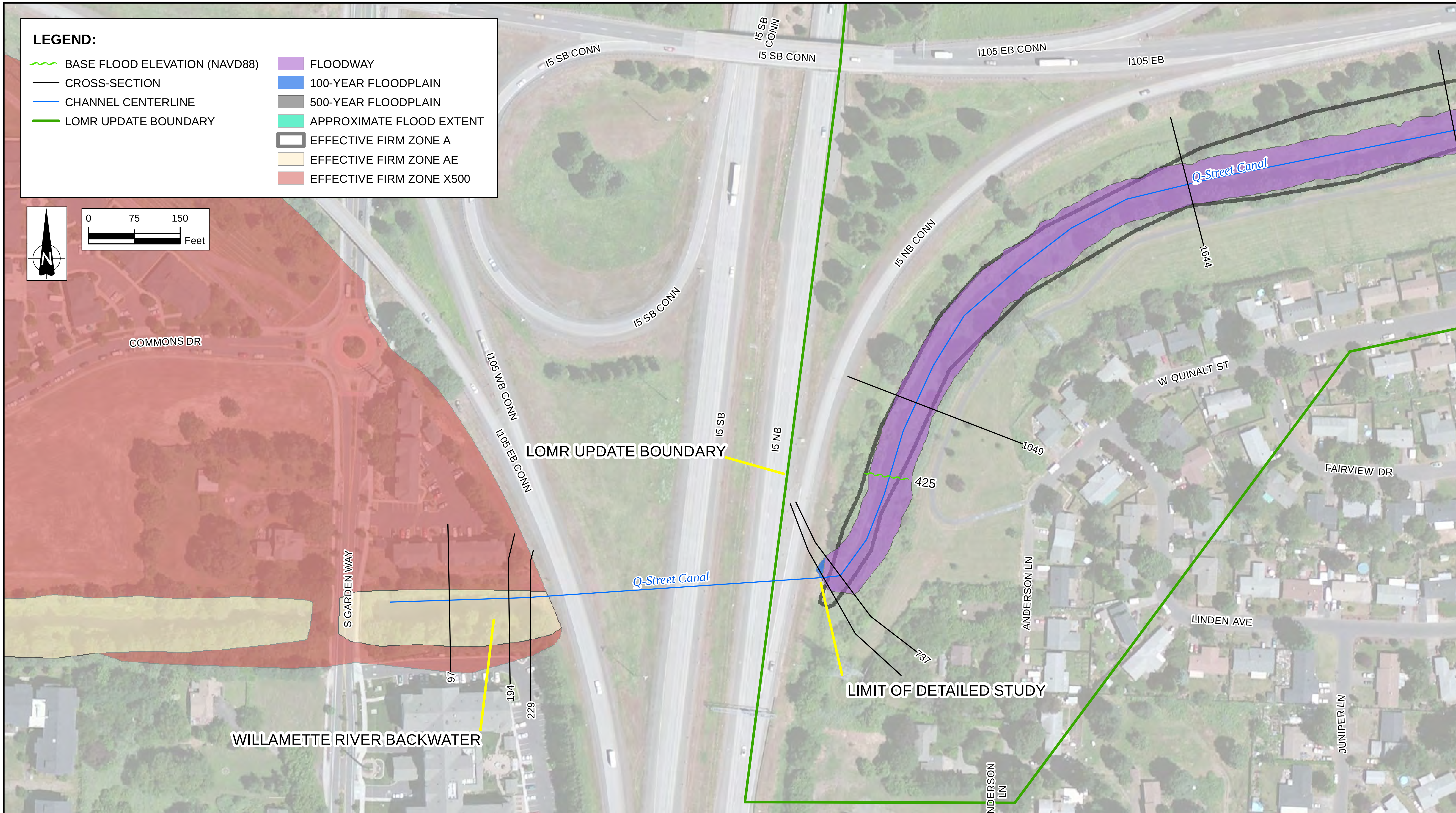

	CITY OF SPRINGFIELD	amec foster wheeler	CHANNEL 6 FIRM UPDATE	DATE	JULY 2016
				SCALE	1 " = 150 '
	Amec Foster Wheeler Environment & Infrastructure, Inc. 7376 S.W. Durham Road Portland, OR 97224		FIGURE 5A - EFFECTIVE FIRM CONCURRENCE Q-STREET CANAL - DOWNSTREAM	PROJECT NO.	6-61M-128571
				FIGURE	5A

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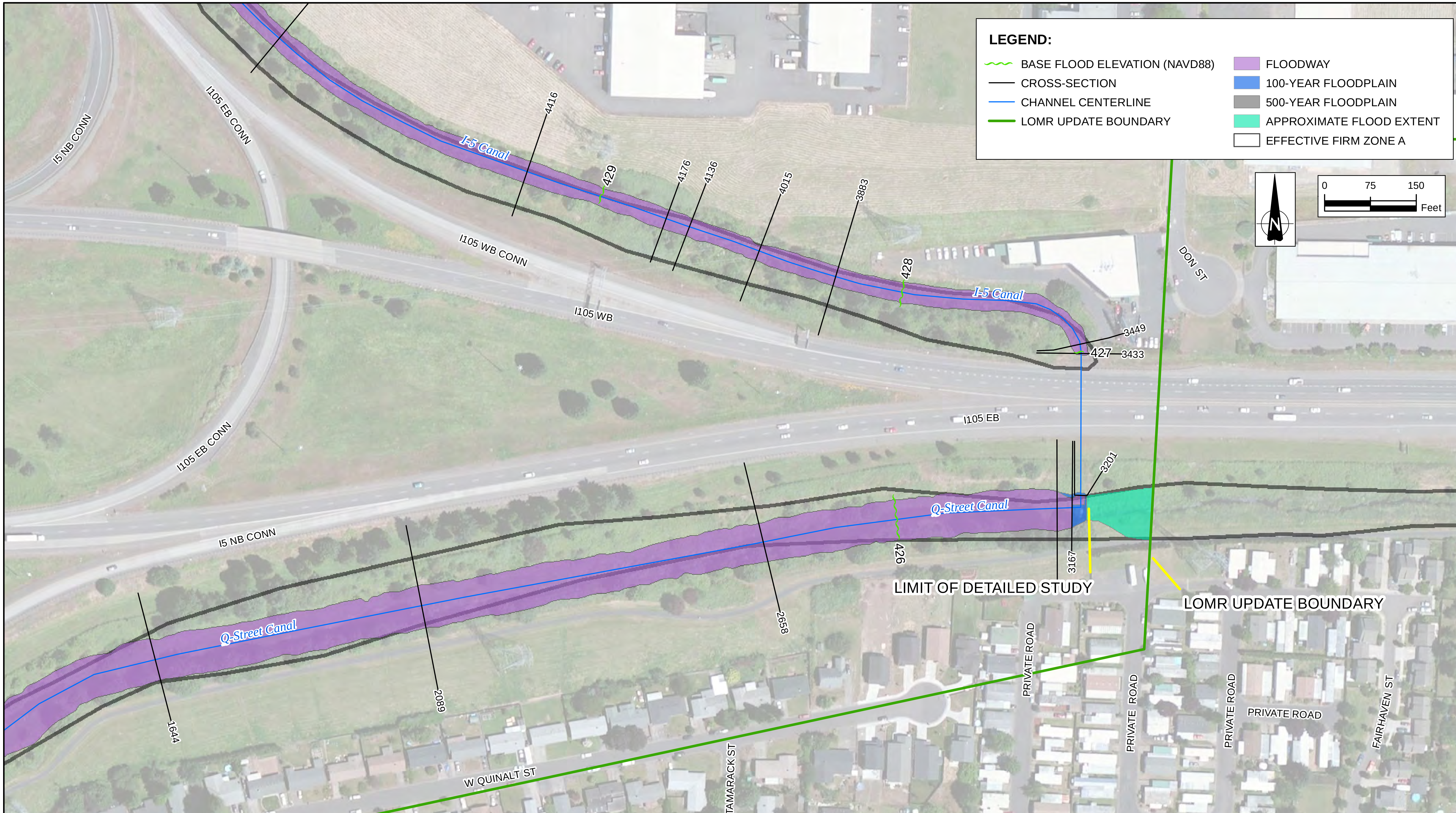

CITY OF SPRINGFIELD	amec foster wheeler	CHANNEL 6 FIRM UPDATE	DATE	JULY 2016
			SCALE	1 " = 150 '
Amec Foster Wheeler Environment & Infrastructure, Inc. 7376 S.W. Durham Road Portland, OR 97224		FIGURE 5B - EFFECTIVE FIRM CONCURRENCE Q-STREET CANAL - UPSTREAM	PROJECT NO.	6-61M-128571
			FIGURE	5B

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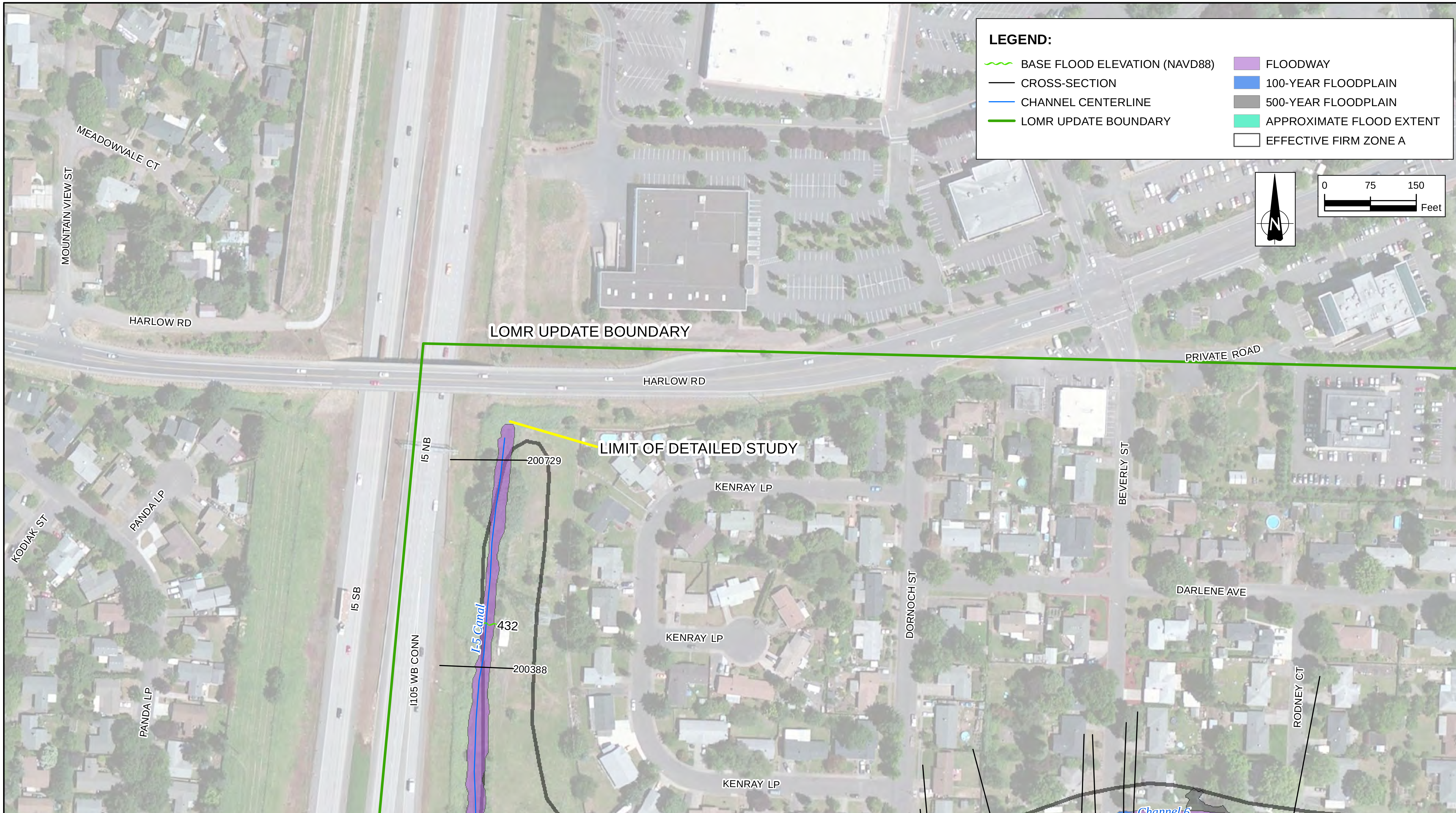

	CITY OF SPRINGFIELD		CHANNEL 6 FIRM UPDATE	DATE JULY 2016
				SCALE 1 " = 150 '
	Amec Foster Wheeler Environment & Infrastructure, Inc. 7376 S.W. Durham Road Portland, OR 97224	amec foster wheeler	FIGURE 5C - EFFECTIVE FIRM CONCURRENCE I-5 CANAL - UPSTREAM	PROJECT NO. 6-61M-128571
				FIGURE 5C

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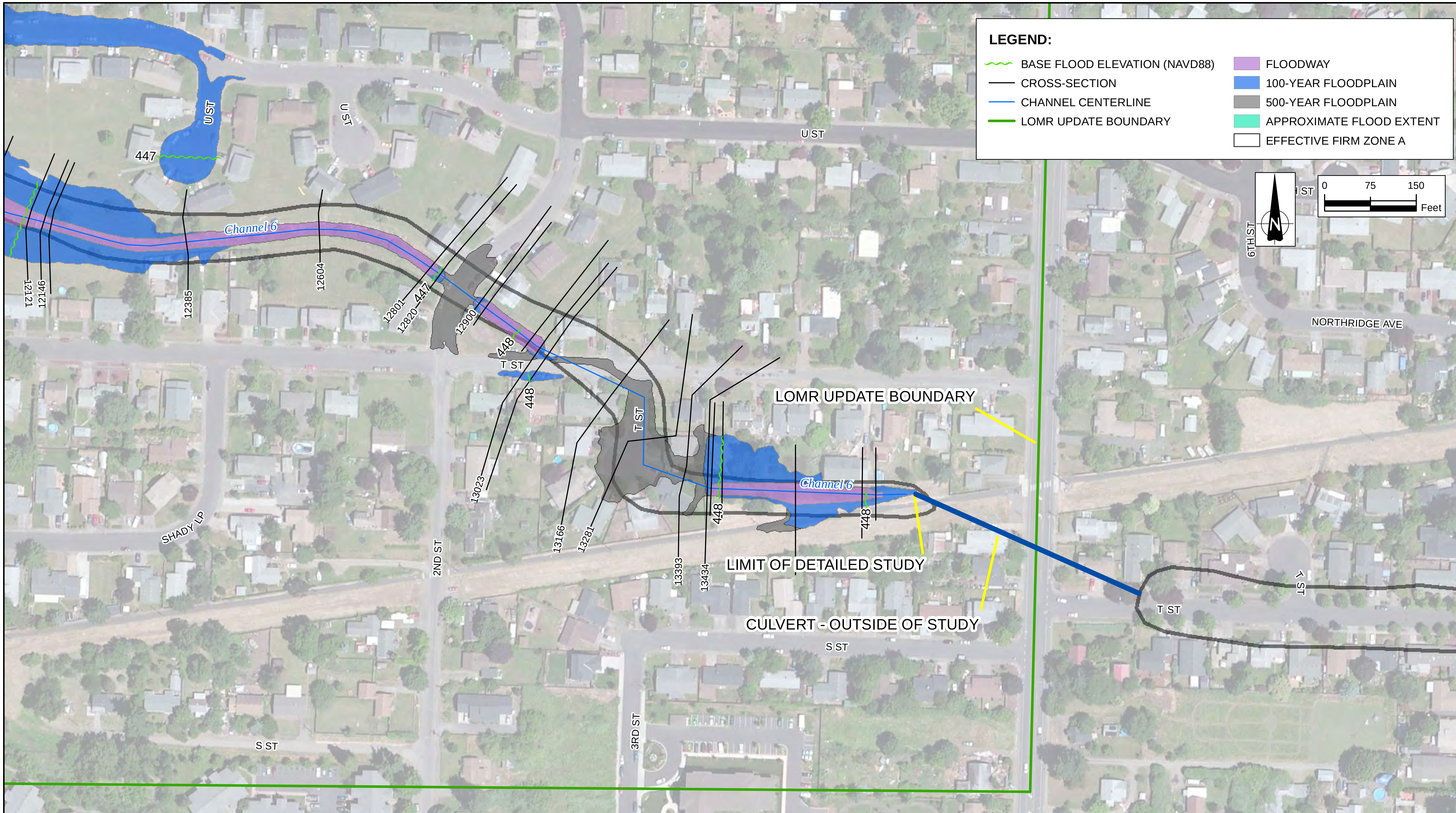

	CITY OF SPRINGFIELD	amec foster wheeler	CHANNEL 6 FIRM UPDATE	DATE JULY 2016
				SCALE 1 " = 150 '
	Amec Foster Wheeler Environment & Infrastructure, Inc. 7376 S.W. Durham Road Portland, OR 97224		FIGURE 5D - EFFECTIVE FIRM CONCURRENCE CHANNEL 6 - UPSTREAM	PROJECT NO. 6-61M-128571
				FIGURE 5D

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