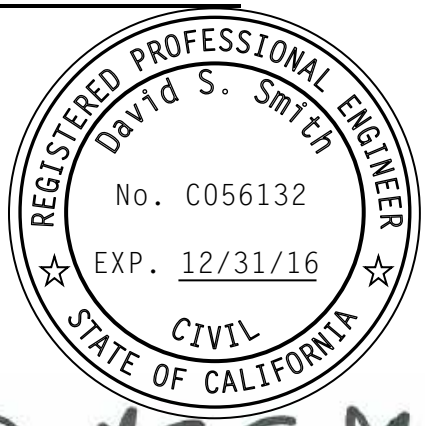
Appendix 11B

Detention and Terracing Evaluation

West Consultants, Inc., December 2016

MEMORANDUM

Project:	Detention and Terracing Evaluation
Subject:	Results Summary
Date:	December 22, 2016
To:	Curt Bates, City of Petaluma Olivia Ervin, City of Petaluma
From:	David S. Smith, P.E., WEST Consultants, Inc.



This memo summarizes the analysis completed by WEST Consultants, Inc. (WEST) for the City of Petaluma (the City) to evaluate the benefit of detention, terracing, and both combined. Previous modeling conducted in 2007 considered the combined effect of terracing and detention but was not based on the hydrology submitted to FEMA for the 2012 map revision. The current evaluation is based on the model used for the 2012 FEMA map revision submittal (xpstorm, version May 2010). The hydrologic percent impervious assumptions within this model were adjusted for Buildout (Year 2025) conditions. Effects of detention and terracing were evaluated for the 10- and 100-year events.

Previous Detention and Terracing Studies

The 2007 "XP-SWMM Model Runs for Floodplain Terraces and Detention Evaluation" summary memo is provided as Exhibit 1 for reference. Since 2007, the xpstorm model hydrology has been updated as part of the 2012 FEMA map revision, as well as some hydraulic elements of the model. The detention basin assumptions are unchanged from the 2007 study.

Terracing in the Denman reach (Corona Road to Petaluma Boulevard) is based on the latest design as described in the 2015 Denman Terracing Phase 3 summary memo which is provided as Exhibit 2 for reference.

Model Simulations

Models comprising the detention, terracing, and both combined (detention and terracing) were created for the 10- and 100-year events. Three alternatives for the terracing extent were considered—1) all terracing reaches included, 2) terracing

upstream of the outlet mall (node pr_0554), and 3) terracing upstream of Corona Road (node pr_0608). Model names are summarized as follows.

- Detention only models:
  - PrefLU10yr_det_8-31-16.xp
  - PrefLU100yr_det_8-31-16.xp
- Terracing only models:
  - PrefLU10yr_terr_10-3-16.xp
  - PrefLU100yr_terr_10-3-16.xp
- Detention and terracing models:
  - PrefLU10yr_det-terr_10-3-16.xp (terracing in all reaches)
  - PrefLU100yr_det-terr_10-3-16.xp (terracing in all reaches)
  - PrefLU10yr_det-terrUS_mall_10-3-16.xp (terracing upstream of mall)
  - PrefLU100yr_det-terrUS_mall_10-3-16.xp (terracing upstream of mall)
  - PrefLU10yr_det-terrUS_Corona_10-3-16.xp (terracing upstream of Corona Road)
  - PrefLU100yr_det-terrUS_Corona_10-3-16.xp (terracing upstream of Corona Road)

Results Comparison

Simulation results compared to "base" conditions (buildout conditions without terracing/detention) are summarized in Table 1 for the 10-year event and Table 2 for the 100-year event. A comparison of results to FEMA water surface elevations is provided in Table 3 for the 100-year event. Tables 1 to 3 rank each simulation result from 1 (best) to 5 (worst), and the following trends are evident:

- The alternative with the best ranking and largest reduction in water surface elevation for all reaches of the Petaluma River is detention and terracing (terracing in all reaches).
- In general, although terracing reduces water surface elevations locally with often significant reductions, the terracing tends to increase the water surface elevation further downstream of the terracing reach by a small amount. This is due to an increase in peak flow, which appears to originate downstream of the confluence of Willow Brook and the Petaluma River. There is less water stored in the Benson and Hummel properties for the terracing scenario (northeast of the Petaluma River/Willow Brook confluence) because the water surface elevation at that point is reduced due to terracing downstream. In other words the increase in peak flow from that point downstream occurs because less is stored in the detention area. A similar effect occurs through the terracing reach—less water is stored in the overbank areas because the terracing is reducing the water surface elevation, so at the peak there is slightly less flow attenuation. At the Willow Brook confluence, the 100-year peak flow for the terracing scenario is

about 160 cfs higher than base conditions, and at Corona Road the 100-year peak is about 270 cfs higher.

- The water surface elevation reduction in a given reach has the same general trends for the 10- and 100-year event, as well as for base or FEMA water surface elevations.
- Comparisons for the 100-year event show that the detention and terracing alternative results in lower water surface elevations than base (or FEMA) conditions for all reaches of the Petaluma River. However, for the 10-year event the terracing and detention results are slightly higher than base conditions.
- Detention alone results in lower water surface elevations than base (or FEMA) conditions for all reaches of the Petaluma River. However, the reduction in water surface elevations is much less—in some cases more than 1.5 feet less—than the results with both detention and terracing.

Flood boundary graphic comparisons are provided in Appendix 1 for the 10-year event and Appendix 2 for the 100-year event. Each appendix includes graphics summarizing: 1) the effect of detention, 2) the effect of terracing, and 3) the effect of detention and terracing. The City requested a fourth flood boundary comparison which has also been included in Appendices 1 and 2—the effect of detention and terracing upstream of the mall (no terracing downstream of the mall). All comparisons in the Appendix 1 and 2 graphics are relative to base conditions (buildout conditions without detention/terracing). Green flood boundary areas represent reductions and red areas represent increases.

Table 4 summarizes the reduction (and increase) in flood boundary extent for the 10- and 100-year events for the various detention and terracing scenarios modeled.

Table 4. Percent Increase and Reduction by Scenario

Scenario	Change in Flood Boundary Extent[1] from Base							
	Increase[2]				Decrease[2]			
	10-year		100-year		10-year		100-year	
	%	Area (ac)	%	Area (ac)	%	Area (ac)	%	Area (ac)
Terracing Only	0.9	3.8	0.7	4.9	11.9	51.8	8.3	60.0
Detention Only	0.2	0.7	0.1	0.8	10.2	44.5	19.5	140.9
Terracing and Detention	0.3	1.1	0.1	0.9	17.1	74.4	25.3	182.9
Terracing U/S of Mall and Detention	0.6	2.5	0.1	0.9	16.1	69.9	23.3	168.3

Notes:

1. Comparison is based on visible area within Appendix 1 and 2 graphics (sheets 1-3 combined).
2. "Increase" from Base Condition means additional flooding (red polygons of flood boundary graphics); "decrease" means a reduction (green polygons).

Conclusions

Based on a review of Tables 1-3 and review of the flood boundary graphics in Appendices 1 and 2, the alternative with detention and terracing (all reaches) represents the most significant reduction in water surface elevation. For the 100-year event, this model run reflects a reduction in water surface elevation throughout the Petaluma River (base and FEMA water surface elevations).

The model run with detention and terracing upstream of the outlet mall is probably the second best overall and results in lower water surface elevations downstream of node pr_0445 (just upstream of the constriction weir), but up to one foot less reduction in the reach between node pr_0445 and pr_0608 (Corona Road). Terracing without detention is not advised due to the increases downstream of the constriction weir (as well as a few reaches upstream of the weir). The scenario with detention and terracing (1) upstream of Corona Road and (2) upstream of the outlet mall are also not advised due to the significant advantage of terracing the entire reach upstream of the constriction weir. Abandoning terracing is also not advised due to the substantial flood reduction in key areas such as the Industrial Avenue corridor, Corona and Capri Creek housing areas, and the outlet mall that occur with terracing.

List of Attachments/Exhibits

Table 1. 10-year Water Surface Elevation Reduction from Base Condition (Buildout)

Table 2. 100-year Water Surface Elevation Reduction from Base Condition (Buildout)

Table 3. 100-year Water Surface Elevation Reduction from FEMA Study Results

Appendix 1. 10-year Event Flood Boundary Graphics
- *Effect of Detention (3 sheets)*
- *Effect of Detention/Terracing (3 sheets)*
- *Effect of Detention and Terracing U/S of Mall (3 sheets)*
- *Effect of Terracing (3 sheets)*

Appendix 2. 100-year Event Flood Boundary Graphics
- *Effect of Detention (3 sheets)*
- *Effect of Detention/Terracing (3 sheets)*
- *Effect of Detention and Terracing U/S of Mall (3 sheets)*
- *Effect of Terracing (3 sheets)*

Exhibit 1. 2007 Detention and Terracing Memo

Exhibit 2. Denman Terracing Phase 3 Memo

Table 1. 10-year Water Surface Elevation Reduction From Base Condition (Buildout)

Reach			Differences from Base Water Surface Elevation (feet)					Rank				
Link ID	U/S Node	D/S Node	terr-det	terr-det USCorona	terr-det USMall	terr	det	terr-det	terr-det USCorona	terr-det US_554	terr	det
lpr_0020	pr_0020	pr_0010	0	0	0	0	0	1	1	1	1	1
lpr_0030	pr_0030	pr_0020	0	0	0	0	0	1	1	1	1	1
lpr_0040	pr_0040	pr_0030	0	0	0	0	0	1	1	1	1	1
lpr_0050	pr_0050	pr_0040	0	0	0	0	0	1	1	1	1	1
lpr_0060	pr_0060	pr_0050	0	0	0	0	0	1	1	1	1	1
lpr_0070	pr_0070	pr_0060	0	0	0	0	0	1	1	1	1	1
lpr_0080	pr_0080	pr_0070	0	0	0	0.012	0	1	1	1	5	1
lpr_0090	pr_0090	pr_0080	0	0	0	0.012	0	1	1	1	5	1
lpr_0100	pr_0094	pr_0090	0	0	0	0.014	0	1	1	1	5	1
Link1230	pr_0096	pr_0094	0	0	0	0.02	0	1	1	1	5	1
Link1229	pr_0098	pr_0096	0	0	0	0.022	0	1	1	1	5	1
Link1228	pr_0100	pr_0098	0	0	0	0.024	0	1	1	1	5	1
lpr_0110	pr_0110	pr_0100	0	0	0	0.028	0	1	1	1	5	1
lpr_0120	pr_0120	pr_0110	0	0	0	0.028	0	1	1	1	5	1
lpr_0130	pr_0130	pr_0120	0	0	0	0.029	-0.011	2	2	2	5	1
lpr_0140	pr_0140	pr_0130	0	0	0	0.032	-0.011	2	2	2	5	1
lpr_0150	pr_0150	pr_0140	0	0	0	0.036	-0.012	2	2	2	5	1
lpr_0160	pr_0160	pr_0150	0	-0.011	-0.011	0.041	-0.014	4	2	2	5	1
lpr_0170	pr_0170	pr_0160	0	-0.012	-0.011	0.043	-0.015	4	2	3	5	1
lpr_0180	pr_0180	pr_0170	0	-0.013	-0.011	0.046	-0.016	4	2	3	5	1
lpr_0190	pr_0190	pr_0180	0	-0.012	-0.011	0.049	-0.016	4	2	3	5	1
lpr_0195	pr_0195	pr_0190	0	-0.014	-0.011	0.055	-0.018	4	2	3	5	1
lpr_0200	pr_0200	pr_0195	0	-0.015	-0.011	0.06	-0.02	4	2	3	5	1
Link1239	pr_0206	pr_0200	0	-0.015	-0.011	0.062	-0.019	4	2	3	5	1
lpr_0208	pr_0208	pr_0206	0.013	-0.017	-0.011	0.068	-0.021	4	2	3	5	1
lpr_0210	pr_0210	pr_0208	0.012	-0.017	-0.011	0.068	-0.022	4	2	3	5	1
lpr_0220	pr_0220	pr_0210	0.014	-0.018	-0.012	0.073	-0.023	4	2	3	5	1
lpr_0230	pr_0230	pr_0220	0.014	-0.019	-0.012	0.073	-0.023	4	2	3	5	1
lpr_0240	pr_0240	pr_0230	0.014	-0.018	-0.011	0.073	-0.023	4	2	3	5	1
lpr_0250	pr_0250	pr_0240	0.014	-0.019	-0.012	0.073	-0.024	4	2	3	5	1
lpr_0260	pr_0260	pr_0250	0.015	-0.018	-0.011	0.074	-0.023	4	2	3	5	1
lpr_0270	pr_0270	pr_0260	0.015	-0.019	-0.011	0.074	-0.024	4	2	3	5	1
lpr_0280	pr_0280	pr_0270	0.016	-0.019	-0.011	0.076	-0.024	4	2	3	5	1
lpr_0290	pr_0290	pr_0280	0.012	-0.017	-0.011	0.069	-0.022	4	2	3	5	1
lpr_0298	pr_0298	pr_0290	0.027	-0.024	-0.011	0.094	-0.03	4	2	3	5	1
lpr_0300	pr_0300	pr_0298	0.032	-0.026	0	0.103	-0.032	4	2	3	5	1
lpr_0308	pr_0308	pr_0300	0.04	-0.029	0	0.144	-0.037	4	2	3	5	1
lpr_0310	pr_0310	pr_0308	0.045	-0.031	0.019	0.172	-0.039	4	2	3	5	1

Table 1. 10-year Water Surface Elevation Reduction From Base Condition (Buildout)

Reach			Differences from Base Water Surface Elevation (feet)					Rank				
Link ID	U/S Node	D/S Node	terr-det	terr-det USCorona	terr-det USMall	terr	det	terr-det	terr-det USCorona	terr-det US_554	terr	det
lpr_0320	pr_0320	pr_0310	0.042	-0.03	0	0.154	-0.038	4	2	3	5	1
lpr_0322	pr_0322	pr_0320										
lpr_0330	pr_0330	pr_0320	0.047	-0.031	0.031	0.185	-0.04	4	2	3	5	1
lpr_0338	pr_0338	pr_0330	0.061	-0.035	0.085	0.258	-0.045	3	2	4	5	1
lpr_0340	pr_0340	pr_0338	0.068	-0.037	0.115	0.298	-0.048	3	2	4	5	1
lpr_0350	pr_0350	pr_0340	0.077	-0.039	0.155	0.348	-0.051	3	2	4	5	1
lpr_0360	pr_0360	pr_0350	0.138	0.028	0.247	0.464	-0.06	3	2	4	5	1
lpr_0370	pr_0370	pr_0360	0.171	0.055	0.284	0.515	-0.081	3	2	4	5	1
lpr_0380	pr_0380	pr_0370	0.178	0.058	0.294	0.535	-0.108	3	2	4	5	1
lpr_0390	pr_0390	pr_0380	0.182	0.059	0.268	0.542	-0.33	3	2	4	5	1
lpr_0400	pr_0400	pr_0390	0.18	0.058	0.255	0.544	-0.364	3	2	4	5	1
lpr_0410	pr_0410	pr_0400										
lpr_0420	pr_0420	pr_0400	0.179	0.058	0.24	0.555	-0.38	3	2	4	5	1
lpr_0430	pr_0430	pr_0420	0.179	0.06	0.232	0.564	-0.392	3	2	4	5	1
lpr_0440	pr_0440	pr_0430	0.278	0.107	0.32	0.951	-0.646	3	2	4	5	1
lpr_0445	pr_0445	pr_0440	-0.284	0.076	0.22	0.328	-0.454	2	3	4	5	1
lpr_0448	pr_0448	pr_0445	-0.332	0.07	0.2	0.24	-0.412	2	3	4	5	1
lpr_0450	pr_0450	pr_0448	-0.456	0.066	0.186	0.104	-0.386	1	3	5	4	2
lpr_0452	pr_0452	pr_0450	-0.539	0.063	0.175	0.011	-0.372	1	4	5	3	2
lpr_0458	pr_0458	pr_0452	-0.707	0.06	0.163	-0.168	-0.35	1	4	5	3	2
lpr_0460	pr_0460	pr_0458	-0.786	0.059	0.161	-0.25	-0.348	1	4	5	3	2
lpr_0465	pr_0465	pr_0460	-0.942	0.057	0.155	-0.41	-0.344	1	4	5	2	3
lpr_0470	pr_0470	pr_0465	-0.852	0.057	0.15	-0.362	-0.334	1	4	5	2	3
lpr_0480	pr_0480	pr_0470	-0.815	0.056	0.148	-0.349	-0.336	1	4	5	2	3
lpr_0490	pr_0490	pr_0480	-0.81	0.057	0.147	-0.39	-0.335	1	4	5	2	3
lpr_0496	pr_0496	pr_0490	-0.832	0.053	0.135	-0.439	-0.314	1	4	5	2	3
lpr_0498	pr_0498	pr_0496	-0.625	0.059	0.149	-0.214	-0.355	1	4	5	3	2
lpr_0500	pr_0500	pr_0498	-0.603	0.06	0.15	-0.191	-0.358	1	4	5	3	2
lpr_0510	pr_0510	pr_0500	-0.565	0.059	0.149	-0.181	-0.358	1	4	5	3	2
lpr_0520	pr_0520	pr_0510	-0.465	0.059	0.147	-0.118	-0.358	1	4	5	3	2
lpr_0530	pr_0530n	pr_0520	-0.756	0.068	0.171	-0.397	-0.419	1	4	5	3	2
lpr_0540	pr_0540n	pr_0530n	-1.328	0.057	0.149	-0.951	-0.362	1	4	5	2	3
lpr_0550	pr_0550	pr_0540n	-1.121	0.063	0.257	-0.693	-0.431	1	4	5	2	3
lpr_0552	pr_0552	pr_0550	-0.727	0.065	0.305	-0.266	-0.468	1	4	5	3	2
3876.1	pr_0554	pr_0552	-0.74	0.064	0.43	-0.279	-0.468	1	4	5	3	2
3876.2	pr_0554	pr_0552	-0.74	0.064	0.43	-0.279	-0.468	1	4	5	3	2
lpr_0560	pr_0560	pr_0554	-0.548	0.07	0.272	-0.065	-0.497	1	4	5	3	2
lpr_0570	pr_0570	pr_0560	-0.083	0.013	-0.127	-0.026	-0.097	3	5	1	4	2

Table 1. 10-year Water Surface Elevation Reduction From Base Condition (Buildout)

Reach			Differences from Base Water Surface Elevation (feet)					Rank				
Link ID	U/S Node	D/S Node	terr-det	terr-det USCorona	terr-det USMall	terr	det	terr-det	terr-det USCorona	terr-det US_554	terr	det
lpr_0580	pr_0580	pr_0570	-0.83	0.018	-0.863	-0.74	-0.133	2	5	1	3	4
lpr_0590	pr_0590n	pr_0580	-1.892	0.041	-1.91	-1.712	-0.279	2	5	1	3	4
lpr_0600	pr_0600n	pr_0590n	-1.786	0.03	-1.8	-1.494	-0.197	2	5	1	3	4
lpr_0606	pr_0606n	pr_0600n	-2.234	0.024	-2.248	-1.913	-0.199	2	5	1	3	4
UWCorona	pr_0607n	pr_0606n										
2150.1	pr_0607n	pr_0606n	-1.962	0.028	-1.973	-1.615	-0.229	2	5	1	3	4
lpr_0608	pr_0608n	pr_0607n	-1.914	0.029	-1.925	-1.567	-0.231	2	5	1	3	4
lpr_0610	pr_0610n	pr_0608n	-1.801	0.076	-1.808	-1.475	-0.274	2	5	1	3	4
lpr_0612	pr_0612n	pr_0610n	-1.439	0.087	-1.444	-1.086	-0.263	2	5	1	3	4
lpr_0614	pr_0614n	pr_0612n	-1.279	0.099	-1.284	-0.966	-0.273	2	5	1	3	4
lpr_0616	pr_0616n	pr_0614n	-1.215	0.104	-1.219	-0.904	-0.271	2	5	1	3	4
lpr_0618	pr_0618n	pr_0616n	-0.671	0.104	-0.674	-0.459	-0.247	2	5	1	3	4
lpr_0620	pr_0620n	pr_0618n	-0.399	0.074	-0.4	-0.183	-0.329	2	5	1	4	3
lpr_0630	pr_0630n	pr_0620n	-0.469	-0.038	-0.47	-0.243	-0.389	2	5	1	4	3
lpr_0640	pr_0640n	pr_0630n	-0.937	-0.549	-0.937	-0.702	-0.424	1	4	1	3	5
lpr_0650	pr_0650	pr_0640n	-0.776	-0.454	-0.776	-0.565	-0.411	1	4	1	3	5
lpr_0660	pr_0660	pr_0650	-0.812	-0.509	-0.812	-0.603	-0.363	1	4	1	3	5
lpr_0670	pr_0670n	pr_0660	-0.451	-0.274	-0.451	-0.243	-0.387	1	4	1	5	3
lpr_0680	pr_0680n	pr_0670n	-0.43	-0.259	-0.43	-0.222	-0.386	1	4	1	5	3
682lob	pr_0682	pr_0680n										
2792.1	pr_0682	pr_0680n	-0.419	-0.252	-0.419	-0.203	-0.408	1	4	1	5	3
684lob	pr_0684	pr_0682										
2791.1	pr_0684	pr_0682	-0.385	-0.227	-0.385	-0.166	-0.417	2	4	2	5	1
lpr_0690	pr_0690n	pr_0684	-0.399	-0.237	-0.399	-0.179	-0.418	2	4	2	5	1
lpr_0700	pr_0700	pr_0690n	-0.49	-0.337	-0.49	-0.274	-0.354	1	4	1	5	3
lpr_0710	pr_0710	pr_0700	-0.603	-0.574	-0.603	-0.505	-0.404	1	3	1	4	5
lpr_0720	pr_0720	pr_0710	-0.878	-0.861	-0.878	-0.776	-0.171	1	3	1	4	5
L1208	pr_0720	det_4										
lpr_0723	pr_0723	pr_0720	-1.75	-1.739	-1.75	-1.678	-0.099	1	3	1	4	5
3663.1	pr_0725	pr_0723	-1.19	-1.181	-1.19	-1.116	-0.028	1	3	1	4	5
3663.2	pr_0725	pr_0723	-1.19	-1.181	-1.19	-1.116	-0.028	1	3	1	4	5
lpr_0730	pr_0730	pr_0725	-1.402	-1.394	-1.402	-1.33	0	1	3	1	4	5
lpr_0740	pr_0740	pr_0730	-1.33	-1.323	-1.33	-1.265	0.01	1	3	1	4	5
2526.1	pr_0745	pr_0740	-0.986	-0.981	-0.986	-0.926	0	1	3	1	4	5
2526.2	pr_0745	pr_0740	-0.986	-0.981	-0.986	-0.926	0	1	3	1	4	5
lpr_0750	pr_0750	pr_0745	-0.849	-0.844	-0.849	-0.79	0	1	3	1	4	5
lpr_0760	pr_0760	pr_0750	-0.736	-0.732	-0.736	-0.684	0	1	3	1	4	5

Table 2. 100-year Water Surface Elevation Reduction From Base Condition (Buildout)

Reach			Differences from Base Water Surface Elevation (feet)					Rank				
Link ID	U/S Node	D/S Node	terr-det	terr-det USCorona	terr-det USMall	terr	det	terr-det	terr-det USCorona	terr-det USMall	terr	det
lpr_0020	pr_0020	pr_0010	0	0	0	0	0	1	1	1	1	1
lpr_0030	pr_0030	pr_0020	0	0	0	0	0	1	1	1	1	1
lpr_0040	pr_0040	pr_0030	0	0	0	0.011	0	1	1	1	5	1
lpr_0050	pr_0050	pr_0040	-0.03	-0.031	-0.033	0.042	-0.033	4	3	1	5	1
lpr_0060	pr_0060	pr_0050	-0.051	-0.049	-0.051	0.057	-0.051	1	4	1	5	1
lpr_0070	pr_0070	pr_0060	-0.073	-0.078	-0.078	0.063	-0.08	4	2	2	5	1
lpr_0080	pr_0080	pr_0070	-0.082	-0.09	-0.089	0.067	-0.093	4	2	3	5	1
lpr_0090	pr_0090	pr_0080	-0.218	-0.24	-0.231	0.165	-0.245	4	2	3	5	1
lpr_0100	pr_0094	pr_0090	-0.222	-0.253	-0.235	0.166	-0.258	4	2	3	5	1
Link1230	pr_0096	pr_0094	-0.242	-0.328	-0.257	0.173	-0.333	4	2	3	5	1
Link1229	pr_0098	pr_0096	-0.248	-0.352	-0.263	0.175	-0.36	4	2	3	5	1
Link1228	pr_0100	pr_0098	-0.253	-0.36	-0.27	0.177	-0.383	4	2	3	5	1
lpr_0110	pr_0110	pr_0100	-0.26	-0.37	-0.278	0.179	-0.415	4	2	3	5	1
lpr_0120	pr_0120	pr_0110	-0.26	-0.37	-0.278	0.178	-0.416	4	2	3	5	1
lpr_0130	pr_0130	pr_0120	-0.266	-0.378	-0.285	0.179	-0.44	4	2	3	5	1
lpr_0140	pr_0140	pr_0130	-0.271	-0.384	-0.29	0.181	-0.448	4	2	3	5	1
lpr_0150	pr_0150	pr_0140	-0.279	-0.397	-0.301	0.183	-0.462	4	2	3	5	1
lpr_0160	pr_0160	pr_0150	-0.292	-0.415	-0.316	0.187	-0.48	4	2	3	5	1
lpr_0170	pr_0170	pr_0160	-0.298	-0.423	-0.323	0.187	-0.489	4	2	3	5	1
lpr_0180	pr_0180	pr_0170	-0.303	-0.431	-0.328	0.189	-0.497	4	2	3	5	1
lpr_0190	pr_0190	pr_0180	-0.308	-0.437	-0.335	0.19	-0.505	4	2	3	5	1
lpr_0195	pr_0195	pr_0190	-0.342	-0.481	-0.374	0.226	-0.552	4	2	3	5	1
lpr_0200	pr_0200	pr_0195	-0.358	-0.5	-0.395	0.23	-0.57	4	2	3	5	1
Link1239	pr_0206	pr_0200	-0.362	-0.506	-0.401	0.231	-0.576	4	2	3	5	1
lpr_0208	pr_0208	pr_0206	-0.393	-0.544	-0.44	0.242	-0.616	4	2	3	5	1
lpr_0210	pr_0210	pr_0208	-0.411	-0.564	-0.459	0.249	-0.635	4	2	3	5	1
lpr_0220	pr_0220	pr_0210	-0.438	-0.602	-0.493	0.267	-0.678	4	2	3	5	1
lpr_0230	pr_0230	pr_0220	-0.444	-0.61	-0.5	0.268	-0.687	4	2	3	5	1
lpr_0240	pr_0240	pr_0230	-0.445	-0.611	-0.501	0.269	-0.689	4	2	3	5	1
lpr_0250	pr_0250	pr_0240	-0.446	-0.612	-0.501	0.269	-0.689	4	2	3	5	1
lpr_0260	pr_0260	pr_0250	-0.447	-0.613	-0.502	0.269	-0.69	4	2	3	5	1
lpr_0270	pr_0270	pr_0260	-0.447	-0.613	-0.502	0.269	-0.691	4	2	3	5	1
lpr_0280	pr_0280	pr_0270	-0.448	-0.615	-0.504	0.269	-0.692	4	2	3	5	1
lpr_0290	pr_0290	pr_0280	-0.434	-0.598	-0.485	0.271	-0.678	4	2	3	5	1
lpr_0298	pr_0298	pr_0290	-0.468	-0.642	-0.538	0.263	-0.717	4	2	3	5	1
lpr_0300	pr_0300	pr_0298	-0.478	-0.653	-0.553	0.261	-0.727	4	2	3	5	1
lpr_0308	pr_0308	pr_0300	-0.505	-0.69	-0.592	0.262	-0.764	4	2	3	5	1
lpr_0310	pr_0310	pr_0308	-0.511	-0.695	-0.601	0.256	-0.768	4	2	3	5	1

Table 2. 100-year Water Surface Elevation Reduction From Base Condition (Buildout)

Reach			Differences from Base Water Surface Elevation (feet)					Rank				
Link ID	U/S Node	D/S Node	terr-det	terr-det USCorona	terr-det USMall	terr	det	terr-det	terr-det USCorona	terr-det USMall	terr	det
lpr_0320	pr_0320	pr_0310	-0.503	-0.685	-0.59	0.256	-0.757	4	2	3	5	1
lpr_0322	pr_0322	pr_0320										
lpr_0330	pr_0330	pr_0320	-0.509	-0.692	-0.601	0.251	-0.764	4	2	3	5	1
lpr_0338	pr_0338	pr_0330	-0.517	-0.712	-0.625	0.236	-0.782	4	2	3	5	1
lpr_0340	pr_0340	pr_0338	-0.529	-0.727	-0.642	0.233	-0.796	4	2	3	5	1
lpr_0350	pr_0350	pr_0340	-0.535	-0.732	-0.653	0.236	-0.798	4	2	3	5	1
lpr_0360	pr_0360	pr_0350	-0.559	-0.756	-0.689	0.235	-0.816	4	2	3	5	1
lpr_0370	pr_0370	pr_0360	-0.578	-0.779	-0.715	0.234	-0.838	4	2	3	5	1
lpr_0380	pr_0380	pr_0370	-0.591	-0.797	-0.734	0.228	-0.857	4	2	3	5	1
lpr_0390	pr_0390	pr_0380	-0.634	-0.84	-0.801	0.203	-0.88	4	2	3	5	1
lpr_0400	pr_0400	pr_0390	-0.669	-0.882	-0.848	0.196	-0.917	4	2	3	5	1
lpr_0410	pr_0410	pr_0400										
lpr_0420	pr_0420	pr_0400	-0.73	-0.951	-0.925	0.191	-0.978	4	2	3	5	1
lpr_0430	pr_0430	pr_0420	-0.771	-0.996	-0.977	0.189	-1.019	4	2	3	5	1
lpr_0440	pr_0440	pr_0430	-0.648	-0.718	-0.775	0.116	-0.775	4	3	1	5	1
lpr_0445	pr_0445	pr_0440	-0.82	-0.736	-0.799	-0.022	-0.8	1	4	3	5	2
lpr_0448	pr_0448	pr_0445	-0.854	-0.741	-0.805	-0.048	-0.806	1	4	3	5	2
lpr_0450	pr_0450	pr_0448	-0.901	-0.722	-0.786	-0.098	-0.788	1	4	3	5	2
lpr_0452	pr_0452	pr_0450	-0.934	-0.707	-0.771	-0.134	-0.774	1	4	3	5	2
lpr_0458	pr_0458	pr_0452	-1.062	-0.731	-0.795	-0.255	-0.799	1	4	3	5	2
lpr_0460	pr_0460	pr_0458	-1.118	-0.73	-0.795	-0.308	-0.8	1	4	3	5	2
lpr_0465	pr_0465	pr_0460	-1.229	-0.729	-0.794	-0.413	-0.8	1	4	3	5	2
lpr_0470	pr_0470	pr_0465	-1.213	-0.727	-0.792	-0.399	-0.799	1	4	3	5	2
lpr_0480	pr_0480	pr_0470	-1.238	-0.739	-0.806	-0.406	-0.814	1	4	3	5	2
lpr_0490	pr_0490	pr_0480	-1.205	-0.688	-0.751	-0.402	-0.761	1	4	3	5	2
lpr_0496	pr_0496	pr_0490	-1.224	-0.683	-0.745	-0.424	-0.756	1	4	3	5	2
lpr_0498	pr_0498	pr_0496	-1.249	-0.814	-0.891	-0.291	-0.906	1	4	3	5	2
lpr_0500	pr_0500	pr_0498	-1.247	-0.824	-0.901	-0.281	-0.917	1	4	3	5	2
lpr_0510	pr_0510	pr_0500	-1.257	-0.813	-0.891	-0.298	-0.907	1	4	3	5	2
lpr_0520	pr_0520	pr_0510	-1.168	-0.685	-0.748	-0.289	-0.762	1	4	3	5	2
lpr_0530	pr_0530n	pr_0520	-1.687	-0.683	-0.755	-0.806	-0.772	1	5	4	2	3
lpr_0540	pr_0540n	pr_0530n	-1.995	-0.696	-0.769	-1.056	-0.786	1	5	4	2	3
lpr_0550	pr_0550	pr_0540n	-1.787	-1.045	-1.101	-0.949	-1.143	1	4	3	5	2
lpr_0552	pr_0552	pr_0550	-1.797	-1.065	-1.122	-0.92	-1.169	1	4	3	5	2
3876.1	pr_0554	pr_0552	-1.836	-1.127	-1.185	-0.992	-1.23	1	4	3	5	2
3876.2	pr_0554	pr_0552	-1.836	-1.127	-1.185	-0.992	-1.23	1	4	3	5	2
lpr_0560	pr_0560	pr_0554	-2.009	-0.931	-0.979	-0.623	-1.037	1	4	3	5	2
lpr_0570	pr_0570	pr_0560	-1.332	-0.745	-0.841	-0.46	-0.835	1	4	2	5	3

Table 2. 100-year Water Surface Elevation Reduction From Base Condition (Buildout)

Reach			Differences from Base Water Surface Elevation (feet)					Rank				
Link ID	U/S Node	D/S Node	terr-det	terr-det USCorona	terr-det USMall	terr	det	terr-det	terr-det USCorona	terr-det USMall	terr	det
lpr_0580	pr_0580	pr_0570	-1.502	-0.504	-1.118	-0.718	-0.571	1	5	2	3	4
lpr_0590	pr_0590n	pr_0580	-1.884	-0.293	-1.479	-0.758	-0.365	1	5	2	3	4
lpr_0600	pr_0600n	pr_0590n	-1.561	-0.238	-1.325	-0.756	-0.315	1	5	2	3	4
lpr_0606	pr_0606n	pr_0600n	-1.797	-0.2	-1.592	-0.995	-0.284	1	5	2	3	4
UWCorona	pr_0607n	pr_0606n										
2150.1	pr_0607n	pr_0606n	-1.741	-0.292	-1.578	-0.939	-0.424	1	5	2	3	4
lpr_0608	pr_0608n	pr_0607n	-1.71	-0.295	-1.553	-0.913	-0.43	1	5	2	3	4
lpr_0610	pr_0610n	pr_0608n	-1.398	-0.255	-1.26	-0.578	-0.401	1	5	2	3	4
lpr_0612	pr_0612n	pr_0610n	-1.208	-0.244	-1.101	-0.493	-0.389	1	5	2	3	4
lpr_0614	pr_0614n	pr_0612n	-1.169	-0.258	-1.075	-0.432	-0.422	1	5	2	3	4
lpr_0616	pr_0616n	pr_0614n	-1.114	-0.252	-1.029	-0.392	-0.421	1	5	2	4	3
lpr_0618	pr_0618n	pr_0616n	-0.913	-0.234	-0.853	-0.308	-0.397	1	5	2	4	3
lpr_0620	pr_0620n	pr_0618n	-0.584	-0.228	-0.564	-0.167	-0.349	1	4	2	5	3
lpr_0630	pr_0630n	pr_0620n	-0.693	-0.398	-0.674	-0.217	-0.345	1	3	2	5	4
lpr_0640	pr_0640n	pr_0630n	-1.285	-1.109	-1.265	-0.892	-0.458	1	3	2	4	5
lpr_0650	pr_0650	pr_0640n	-1.176	-1.009	-1.159	-0.778	-0.457	1	3	2	4	5
lpr_0660	pr_0660	pr_0650	-1.17	-1.007	-1.153	-0.775	-0.452	1	3	2	4	5
lpr_0670	pr_0670n	pr_0660	-0.812	-0.703	-0.805	-0.446	-0.425	1	3	2	4	5
lpr_0680	pr_0680n	pr_0670n	-0.801	-0.693	-0.794	-0.429	-0.427	1	3	2	4	5
682lob	pr_0682	pr_0680n										
2792.1	pr_0682	pr_0680n	-0.669	-0.561	-0.656	-0.307	-0.352	1	3	2	5	4
684lob	pr_0684	pr_0682										
2791.1	pr_0684	pr_0682	-0.495	-0.454	-0.491	-0.211	-0.321	1	3	2	5	4
lpr_0690	pr_0690n	pr_0684	-0.511	-0.467	-0.51	-0.223	-0.32	1	3	2	5	4
lpr_0700	pr_0700	pr_0690n	-0.542	-0.499	-0.542	-0.252	-0.319	1	3	1	5	4
lpr_0710	pr_0710	pr_0700	-0.641	-0.619	-0.64	-0.407	-0.07	1	3	2	4	5
lpr_0720	pr_0720	pr_0710	-0.909	-0.886	-0.909	-0.619	-0.171	1	3	1	4	5
L1208	pr_0720	det_4										
lpr_0723	pr_0723	pr_0720	-1.569	-1.552	-1.569	-1.333	-0.047	1	3	1	4	5
3663.1	pr_0725	pr_0723	-0.307	-0.303	-0.307	-0.251	-0.012	1	3	1	4	5
3663.2	pr_0725	pr_0723	-0.307	-0.303	-0.307	-0.251	-0.012	1	3	1	4	5
lpr_0730	pr_0730	pr_0725	-0.428	-0.424	-0.428	-0.37	-0.012	1	3	1	4	5
lpr_0740	pr_0740	pr_0730	-0.526	-0.522	-0.525	-0.464	-0.02	1	3	2	4	5
2526.1	pr_0745	pr_0740	-0.332	-0.329	-0.332	-0.249	-0.039	1	3	1	4	5
2526.2	pr_0745	pr_0740	-0.332	-0.329	-0.332	-0.249	-0.039	1	3	1	4	5
lpr_0750	pr_0750	pr_0745	-0.606	-0.604	-0.606	-0.524	-0.051	1	3	1	4	5
lpr_0760	pr_0760	pr_0750	-0.556	-0.554	-0.556	-0.467	-0.054	1	3	1	4	5

Table 3. 100-year Water Surface Elevation Reduction From FEMA Study Results

Reach			Differences from FEMA Water Surface Elevation (feet)					Rank				
Link ID	U/S Node	D/S Node	terr-det	terr-det USCorona	terr-det USMall	terr	det	terr-det	terr-det USCorona	terr-det US_554	terr	det
lpr_0020	pr_0020	pr_0010	0	0	0	0	0	1	1	1	1	1
lpr_0030	pr_0030	pr_0020	0	0	0	0	0	1	1	1	1	1
lpr_0040	pr_0040	pr_0030	0	0	0	0.015	0	1	1	1	5	1
lpr_0050	pr_0050	pr_0040	-0.026	-0.027	-0.029	0.046	-0.029	4	3	1	5	1
lpr_0060	pr_0060	pr_0050	-0.046	-0.044	-0.046	0.062	-0.046	1	4	1	5	1
lpr_0070	pr_0070	pr_0060	-0.067	-0.072	-0.072	0.069	-0.074	4	2	2	5	1
lpr_0080	pr_0080	pr_0070	-0.075	-0.083	-0.082	0.074	-0.086	4	2	3	5	1
lpr_0090	pr_0090	pr_0080	-0.192	-0.214	-0.205	0.191	-0.219	4	2	3	5	1
lpr_0100	pr_0094	pr_0090	-0.196	-0.227	-0.209	0.192	-0.232	4	2	3	5	1
Link1230	pr_0096	pr_0094	-0.216	-0.302	-0.231	0.199	-0.307	4	2	3	5	1
Link1229	pr_0098	pr_0096	-0.222	-0.326	-0.237	0.201	-0.334	4	2	3	5	1
Link1228	pr_0100	pr_0098	-0.227	-0.334	-0.244	0.203	-0.357	4	2	3	5	1
lpr_0110	pr_0110	pr_0100	-0.234	-0.344	-0.252	0.205	-0.389	4	2	3	5	1
lpr_0120	pr_0120	pr_0110	-0.234	-0.344	-0.252	0.204	-0.39	4	2	3	5	1
lpr_0130	pr_0130	pr_0120	-0.239	-0.351	-0.258	0.206	-0.413	4	2	3	5	1
lpr_0140	pr_0140	pr_0130	-0.245	-0.358	-0.264	0.207	-0.422	4	2	3	5	1
lpr_0150	pr_0150	pr_0140	-0.253	-0.371	-0.275	0.209	-0.436	4	2	3	5	1
lpr_0160	pr_0160	pr_0150	-0.266	-0.389	-0.29	0.213	-0.454	4	2	3	5	1
lpr_0170	pr_0170	pr_0160	-0.271	-0.396	-0.296	0.214	-0.462	4	2	3	5	1
lpr_0180	pr_0180	pr_0170	-0.277	-0.405	-0.302	0.215	-0.471	4	2	3	5	1
lpr_0190	pr_0190	pr_0180	-0.281	-0.41	-0.308	0.217	-0.478	4	2	3	5	1
lpr_0195	pr_0195	pr_0190	-0.313	-0.452	-0.345	0.255	-0.523	4	2	3	5	1
lpr_0200	pr_0200	pr_0195	-0.328	-0.47	-0.365	0.26	-0.54	4	2	3	5	1
Link1239	pr_0206	pr_0200	-0.332	-0.476	-0.371	0.261	-0.546	4	2	3	5	1
lpr_0208	pr_0208	pr_0206	-0.361	-0.512	-0.408	0.274	-0.584	4	2	3	5	1
lpr_0210	pr_0210	pr_0208	-0.378	-0.531	-0.426	0.282	-0.602	4	2	3	5	1
lpr_0220	pr_0220	pr_0210	-0.403	-0.567	-0.458	0.302	-0.643	4	2	3	5	1
lpr_0230	pr_0230	pr_0220	-0.409	-0.575	-0.465	0.303	-0.652	4	2	3	5	1
lpr_0240	pr_0240	pr_0230	-0.41	-0.576	-0.466	0.304	-0.654	4	2	3	5	1
lpr_0250	pr_0250	pr_0240	-0.411	-0.577	-0.466	0.304	-0.654	4	2	3	5	1
lpr_0260	pr_0260	pr_0250	-0.411	-0.577	-0.466	0.305	-0.654	4	2	3	5	1
lpr_0270	pr_0270	pr_0260	-0.411	-0.577	-0.466	0.305	-0.655	4	2	3	5	1
lpr_0280	pr_0280	pr_0270	-0.413	-0.58	-0.469	0.304	-0.657	4	2	3	5	1
lpr_0290	pr_0290	pr_0280	-0.399	-0.563	-0.45	0.306	-0.643	4	2	3	5	1
lpr_0298	pr_0298	pr_0290	-0.434	-0.608	-0.504	0.297	-0.683	4	2	3	5	1
lpr_0300	pr_0300	pr_0298	-0.444	-0.619	-0.519	0.295	-0.693	4	2	3	5	1
lpr_0308	pr_0308	pr_0300	-0.47	-0.655	-0.557	0.297	-0.729	4	2	3	5	1
lpr_0310	pr_0310	pr_0308	-0.477	-0.661	-0.567	0.29	-0.734	4	2	3	5	1

Table 3. 100-year Water Surface Elevation Reduction From FEMA Study Results

Reach			Differences from FEMA Water Surface Elevation (feet)					Rank				
Link ID	U/S Node	D/S Node	terr-det	terr-det USCorona	terr-det USMall	terr	det	terr-det	terr-det USCorona	terr-det US_554	terr	det
lpr_0320	pr_0320	pr_0310	-0.469	-0.651	-0.556	0.29	-0.723	4	2	3	5	1
lpr_0322	pr_0322	pr_0320										
lpr_0330	pr_0330	pr_0320	-0.476	-0.659	-0.568	0.284	-0.731	4	2	3	5	1
lpr_0338	pr_0338	pr_0330	-0.486	-0.681	-0.594	0.267	-0.751	4	2	3	5	1
lpr_0340	pr_0340	pr_0338	-0.498	-0.696	-0.611	0.264	-0.765	4	2	3	5	1
lpr_0350	pr_0350	pr_0340	-0.505	-0.702	-0.623	0.266	-0.768	4	2	3	5	1
lpr_0360	pr_0360	pr_0350	-0.53	-0.727	-0.66	0.264	-0.787	4	2	3	5	1
lpr_0370	pr_0370	pr_0360	-0.549	-0.75	-0.686	0.263	-0.809	4	2	3	5	1
lpr_0380	pr_0380	pr_0370	-0.561	-0.767	-0.704	0.258	-0.827	4	2	3	5	1
lpr_0390	pr_0390	pr_0380	-0.605	-0.811	-0.772	0.232	-0.851	4	2	3	5	1
lpr_0400	pr_0400	pr_0390	-0.64	-0.853	-0.819	0.225	-0.888	4	2	3	5	1
lpr_0410	pr_0410	pr_0400										
lpr_0420	pr_0420	pr_0400	-0.7	-0.921	-0.895	0.221	-0.948	4	2	3	5	1
lpr_0430	pr_0430	pr_0420	-0.74	-0.965	-0.946	0.22	-0.988	4	2	3	5	1
lpr_0440	pr_0440	pr_0430	-0.626	-0.696	-0.753	0.138	-0.753	4	3	1	5	1
lpr_0445	pr_0445	pr_0440	-0.797	-0.713	-0.776	0.001	-0.777	1	4	3	5	2
lpr_0448	pr_0448	pr_0445	-0.83	-0.717	-0.781	-0.024	-0.782	1	4	3	5	2
lpr_0450	pr_0450	pr_0448	-0.878	-0.699	-0.763	-0.075	-0.765	1	4	3	5	2
lpr_0452	pr_0452	pr_0450	-0.912	-0.685	-0.749	-0.112	-0.752	1	4	3	5	2
lpr_0458	pr_0458	pr_0452	-1.038	-0.707	-0.771	-0.231	-0.775	1	4	3	5	2
lpr_0460	pr_0460	pr_0458	-1.094	-0.706	-0.771	-0.284	-0.776	1	4	3	5	2
lpr_0465	pr_0465	pr_0460	-1.205	-0.705	-0.77	-0.389	-0.776	1	4	3	5	2
lpr_0470	pr_0470	pr_0465	-1.19	-0.704	-0.769	-0.376	-0.776	1	4	3	5	2
lpr_0480	pr_0480	pr_0470	-1.214	-0.715	-0.782	-0.382	-0.79	1	4	3	5	2
lpr_0490	pr_0490	pr_0480	-1.183	-0.666	-0.729	-0.38	-0.739	1	4	3	5	2
lpr_0496	pr_0496	pr_0490	-1.202	-0.661	-0.723	-0.402	-0.734	1	4	3	5	2
lpr_0498	pr_0498	pr_0496	-1.223	-0.788	-0.865	-0.265	-0.88	1	4	3	5	2
lpr_0500	pr_0500	pr_0498	-1.221	-0.798	-0.875	-0.255	-0.891	1	4	3	5	2
lpr_0510	pr_0510	pr_0500	-1.231	-0.787	-0.865	-0.272	-0.881	1	4	3	5	2
lpr_0520	pr_0520	pr_0510	-1.146	-0.663	-0.726	-0.267	-0.74	1	4	3	5	2
lpr_0530	pr_0530n	pr_0520	-1.668	-0.664	-0.736	-0.787	-0.753	1	5	4	2	3
lpr_0540	pr_0540n	pr_0530n	-1.974	-0.675	-0.748	-1.035	-0.765	1	5	4	2	3
lpr_0550	pr_0550	pr_0540n	-1.766	-1.024	-1.08	-0.928	-1.122	1	4	3	5	2
lpr_0552	pr_0552	pr_0550	-1.776	-1.044	-1.101	-0.899	-1.148	1	4	3	5	2
3876.1	pr_0554	pr_0552	-1.812	-1.103	-1.161	-0.968	-1.206	1	4	3	5	2
3876.2	pr_0554	pr_0552	-1.812	-1.103	-1.161	-0.968	-1.206	1	4	3	5	2
lpr_0560	pr_0560	pr_0554	-1.988	-0.91	-0.958	-0.602	-1.016	1	4	3	5	2
lpr_0570	pr_0570	pr_0560	-1.314	-0.727	-0.823	-0.442	-0.817	1	4	2	5	3

Table 3. 100-year Water Surface Elevation Reduction From FEMA Study Results

Reach			Differences from FEMA Water Surface Elevation (feet)					Rank				
Link ID	U/S Node	D/S Node	terr-det	terr-det USCorona	terr-det USMall	terr	det	terr-det	terr-det USCorona	terr-det US_554	terr	det
lpr_0580	pr_0580	pr_0570	-1.489	-0.491	-1.105	-0.705	-0.558	1	5	2	3	4
lpr_0590	pr_0590n	pr_0580	-1.875	-0.284	-1.47	-0.749	-0.356	1	5	2	3	4
lpr_0600	pr_0600n	pr_0590n	-1.554	-0.231	-1.318	-0.749	-0.308	1	5	2	3	4
lpr_0606	pr_0606n	pr_0600n	-1.791	-0.194	-1.586	-0.989	-0.278	1	5	2	3	4
UWCorona	pr_0607n	pr_0606n										
2150.1	pr_0607n	pr_0606n	-1.733	-0.284	-1.57	-0.931	-0.416	1	5	2	3	4
lpr_0608	pr_0608n	pr_0607n	-1.702	-0.287	-1.545	-0.905	-0.422	1	5	2	3	4
lpr_0610	pr_0610n	pr_0608n	-1.392	-0.249	-1.254	-0.572	-0.395	1	5	2	3	4
lpr_0612	pr_0612n	pr_0610n	-1.202	-0.238	-1.095	-0.487	-0.383	1	5	2	3	4
lpr_0614	pr_0614n	pr_0612n	-1.163	-0.252	-1.069	-0.426	-0.416	1	5	2	3	4
lpr_0616	pr_0616n	pr_0614n	-1.108	-0.246	-1.023	-0.386	-0.415	1	5	2	4	3
lpr_0618	pr_0618n	pr_0616n	-0.908	-0.229	-0.848	-0.303	-0.392	1	5	2	4	3
lpr_0620	pr_0620n	pr_0618n	-0.579	-0.223	-0.559	-0.162	-0.344	1	4	2	5	3
lpr_0630	pr_0630n	pr_0620n	-0.688	-0.393	-0.669	-0.212	-0.34	1	3	2	5	4
lpr_0640	pr_0640n	pr_0630n	-1.279	-1.103	-1.259	-0.886	-0.452	1	3	2	4	5
lpr_0650	pr_0650	pr_0640n	-1.169	-1.002	-1.152	-0.771	-0.45	1	3	2	4	5
lpr_0660	pr_0660	pr_0650	-1.164	-1.001	-1.147	-0.769	-0.446	1	3	2	4	5
lpr_0670	pr_0670n	pr_0660	-0.806	-0.697	-0.799	-0.44	-0.419	1	3	2	4	5
lpr_0680	pr_0680n	pr_0670n	-0.795	-0.687	-0.788	-0.423	-0.421	1	3	2	4	5
682lob	pr_0682	pr_0680n										
2792.1	pr_0682	pr_0680n	-0.663	-0.555	-0.65	-0.301	-0.346	1	3	2	5	4
684lob	pr_0684	pr_0682										
2791.1	pr_0684	pr_0682	-0.49	-0.449	-0.486	-0.206	-0.316	1	3	2	5	4
lpr_0690	pr_0690n	pr_0684	-0.506	-0.462	-0.505	-0.218	-0.315	1	3	2	5	4
lpr_0700	pr_0700	pr_0690n	-0.537	-0.494	-0.537	-0.247	-0.314	1	3	1	5	4
lpr_0710	pr_0710	pr_0700	-0.64	-0.618	-0.639	-0.406	-0.069	1	3	2	4	5
lpr_0720	pr_0720	pr_0710	-0.903	-0.88	-0.903	-0.613	-0.165	1	3	1	4	5
L1208	pr_0720	det_4										
lpr_0723	pr_0723	pr_0720	-1.567	-1.55	-1.567	-1.331	-0.045	1	3	1	4	5
3663.1	pr_0725	pr_0723	-0.307	-0.303	-0.307	-0.251	-0.012	1	3	1	4	5
3663.2	pr_0725	pr_0723	-0.307	-0.303	-0.307	-0.251	-0.012	1	3	1	4	5
lpr_0730	pr_0730	pr_0725	-0.428	-0.424	-0.428	-0.37	-0.012	1	3	1	4	5
lpr_0740	pr_0740	pr_0730	-0.524	-0.52	-0.523	-0.462	-0.018	1	3	2	4	5
2526.1	pr_0745	pr_0740	-0.329	-0.326	-0.329	-0.246	-0.036	1	3	1	4	5
2526.2	pr_0745	pr_0740	-0.329	-0.326	-0.329	-0.246	-0.036	1	3	1	4	5
lpr_0750	pr_0750	pr_0745	-0.602	-0.6	-0.602	-0.52	-0.047	1	3	1	4	5
lpr_0760	pr_0760	pr_0750	-0.552	-0.55	-0.552	-0.463	-0.05	1	3	1	4	5

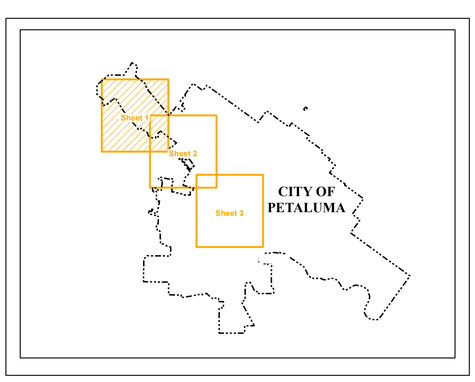
Appendix 1

10-year Event Flood Boundary Graphics

REDWOOD WAY

Legend

- XP-SWMM Nodes
- Stream Centerlines
- Parcels
- Buildings
- City Limits
- Floodplain Area Removed
- No Change
- Floodplain Area Added



City of Petaluma
10-Year Flood Boundary
Effect of Detention
Sheet 1 of 3

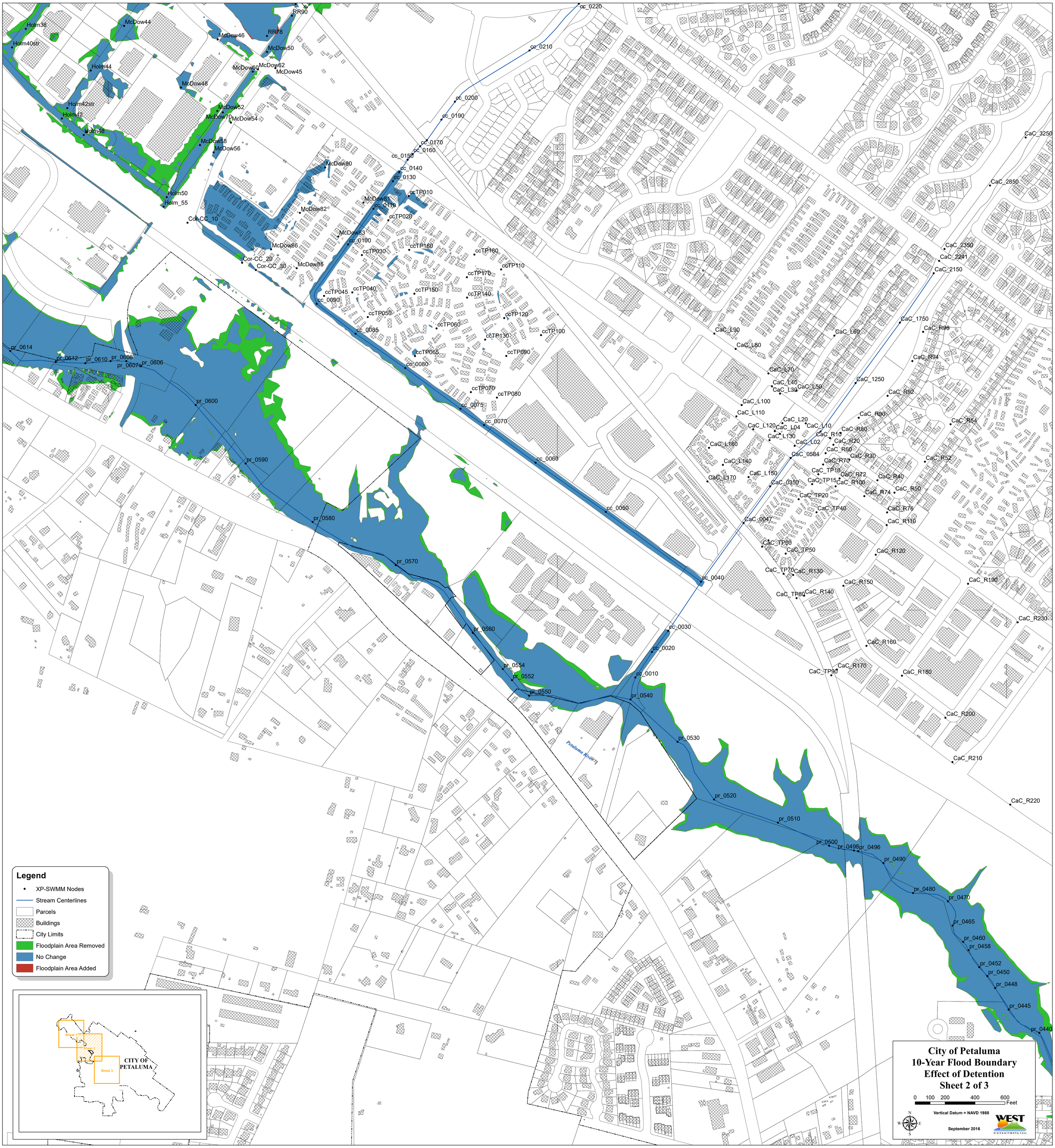
0 100 200 400 600 Feet

Vertical Datum = NAVD 1988

N W E S

September 2016

WEST Consultants, Inc.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RR78
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Holm42str
Holm42
McDow52
McDow70
McDow54
Holm48
McDow58
McDow56
Holm50
Holm_55
Cor-CC_10
McDow80
McDow81
McDow82
McDow83
McDow86
McDow85
Cor-CC_20
Cor-CC_30
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cc_0210
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Petaluma River
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CaC_2850
CaC_2350
CaC_2241
CaC_2150
CaC_1750
CaC_1250
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CaC_L60
CaC_L80
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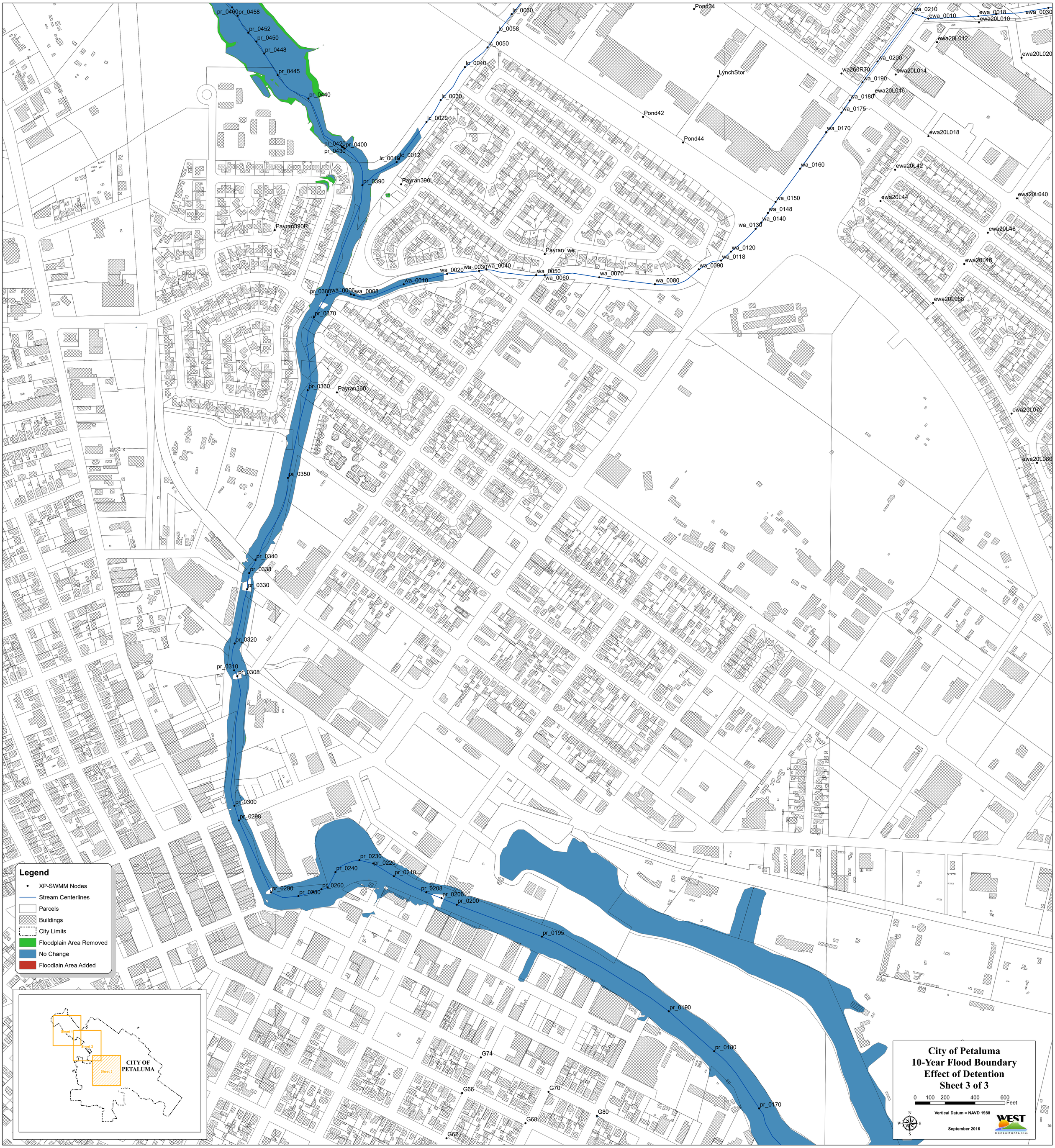
CaC_R180
CaC_R200
CaC_R210
CaC_R220
Legend
XP-SWMM Nodes
Stream Centerlines
Parcels
Buildings
City Limits
Floodplain Area Removed
No Change
Floodplain Area Added
Sheet 1
Sheet 2
Sheet 3
CITY OF PETALUMA
City of Petaluma
10-Year Flood Boundary
Effect of Detention
Sheet 2 of 3
0 100 200 400 600
Feet
Vertical Datum = NAVD 1988
N
W
E
S
September 2016
WEST
Consultants, Inc.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LynchStor
Pond42
Pond44
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Payran390R
Payran_wa
Payran360
G74
G66
G70
G80
G68
G62
Legend
XP-SWMM Nodes
Stream Centerlines
Parcels
Buildings
City Limits
Floodplain Area Removed
No Change
Floodlain Area Added
Sheet 1
Sheet 2
Sheet 3
CITY OF PETALUMA
City of Petaluma
10-Year Flood Boundary
Effect of Detention
Sheet 3 of 3
0 100 200 400 600
Feet
Vertical Datum = NAVD 1988
September 2016
N
W
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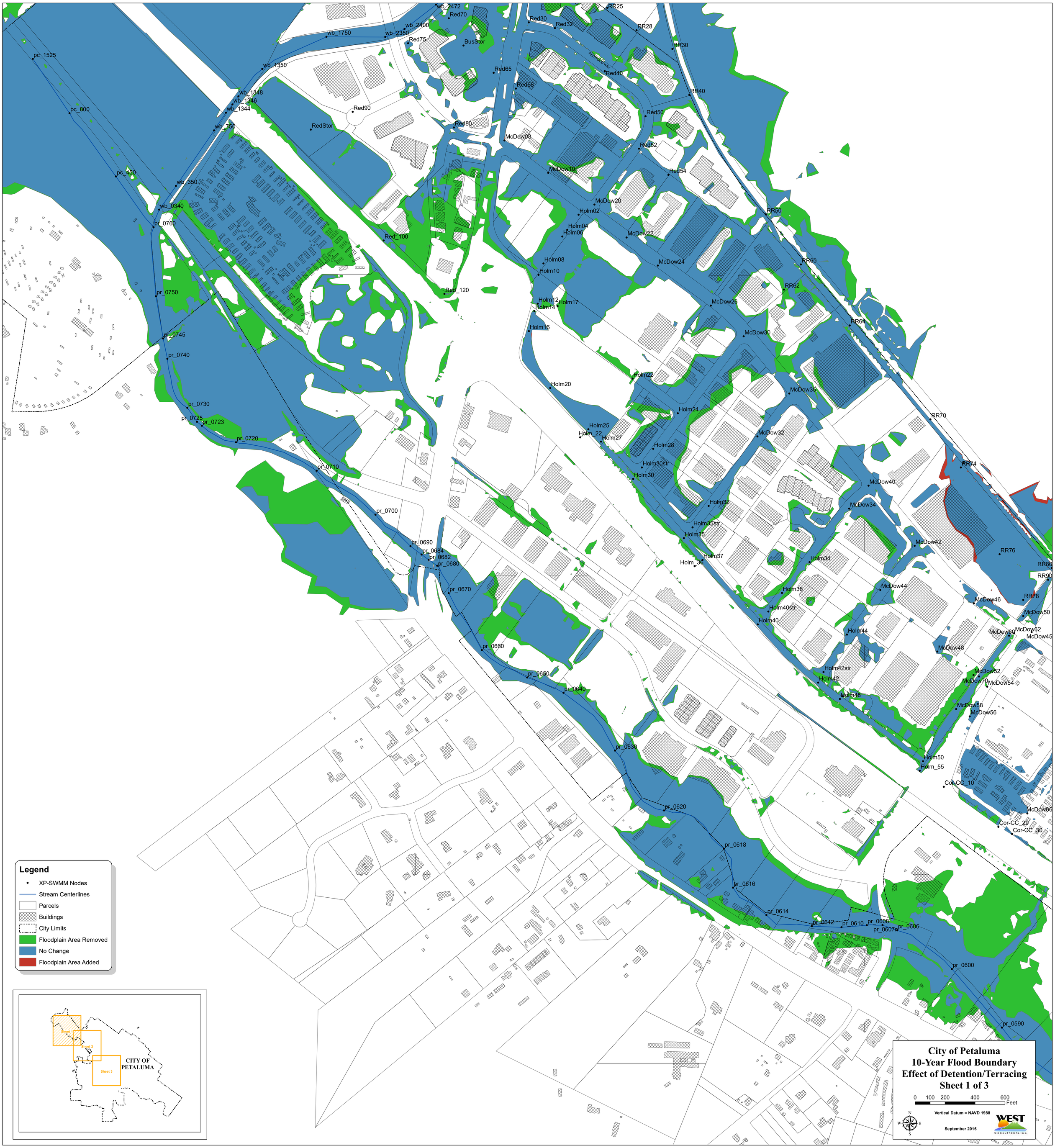
WEST
consultants inc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RR25
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RIDGWOOD WAY
Red40
Red68
wb_1348
wb_1346
RR40
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Red90
Red50
wb_750
RedStor
Red80
McDow08
Red52
pc_450
McDow10
Red54
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McDow20
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RR50
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Holm06
McDow22
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Legend
XP-SWMM Nodes
Stream Centerlines
Parcels
Buildings
City Limits
Floodplain Area Removed
No Change
Floodplain Area Added
Sheet 1
Sheet 2
Sheet 3
CITY OF PETALUMA
City of Petaluma
10-Year Flood Boundary
Effect of Detention/Terracing
Sheet 1 of 3
0 100 200 400 600
Feet
Vertical Datum = NAVD 1988
N
W
E
S
September 2016
WEST
Consultants, Inc.

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Holm40str
RR90
RR78
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McDow50
McDow60
McDow62
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McDow58
McDow56
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McDow82
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CaC_TP90
CaC_R170
CaC_R180
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CaC_R210
CaC_R220
Petaluma River
Legend
XP-SWMM Nodes
Stream Centerlines
Parcels
City Limits
Buildings
Floodplain Area Removed
No Change
Floodplain Area Added
Sheet 1
Sheet 2
Sheet 3
CITY OF PETALUMA
City of Petaluma
10-Year Flood Boundary
Effect of Detention/Terracing
Sheet 2 of 3
0 100 200 400 600 Feet
Vertical Datum = NAVD 1988
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September 2016
WEST Consultants, Inc.

pr_0460 pr_0458 pr_0452 pr_0450 pr_0448 pr_0445 pr_0440 pr_0420 pr_0400 pr_0430 pr_0390 pr_0380 pr_0370 pr_0360 pr_0350 pr_0340 pr_0338 pr_0330 pr_0320 pr_0310 pr_0308 pr_0300 pr_0298 pr_0290 pr_0280 pr_0260 pr_0240 pr_0230 pr_0220 pr_0210 pr_0208 pr_0206 pr_0200 pr_0195 pr_0190 pr_0180 pr_0170

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wa260R70

Pond34 Pond42 Pond44 LynchStor

Payran390L Payran390R Payran_wa Payran360

G74 G66 G70 G80 G68 G62

Legend

- XP-SWMM Nodes
- Stream Centerlines
- Parcels
- Buildings
- City Limits
- Floodplain Area Removed
- No Change
- Floodplain Area Added

Sheet 1
Sheet 2
Sheet 3
CITY OF PETALUMA

City of Petaluma
10-Year Flood Boundary
Effect of Detention/Terracing
Sheet 3 of 3

0 100 200 400 600 Feet

Vertical Datum = NAVD 1988

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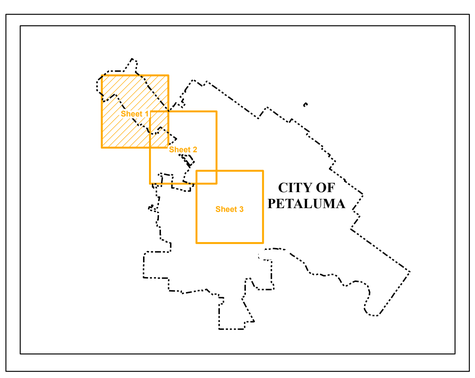
REDWOOD WAY

Legend

- XP-SWMM Nodes
- Stream Centerlines
- Parcels
- Buildings
- City Limits
- Floodplain Area Removed
- No Change
- Floodplain Area Added



City of Petaluma
10-Year Flood Boundary
Effect of Detention and Terracing U/S of Mall
Sheet 1 of 3

0 100 200 400 600 Feet

Vertical Datum = NAVD 1988

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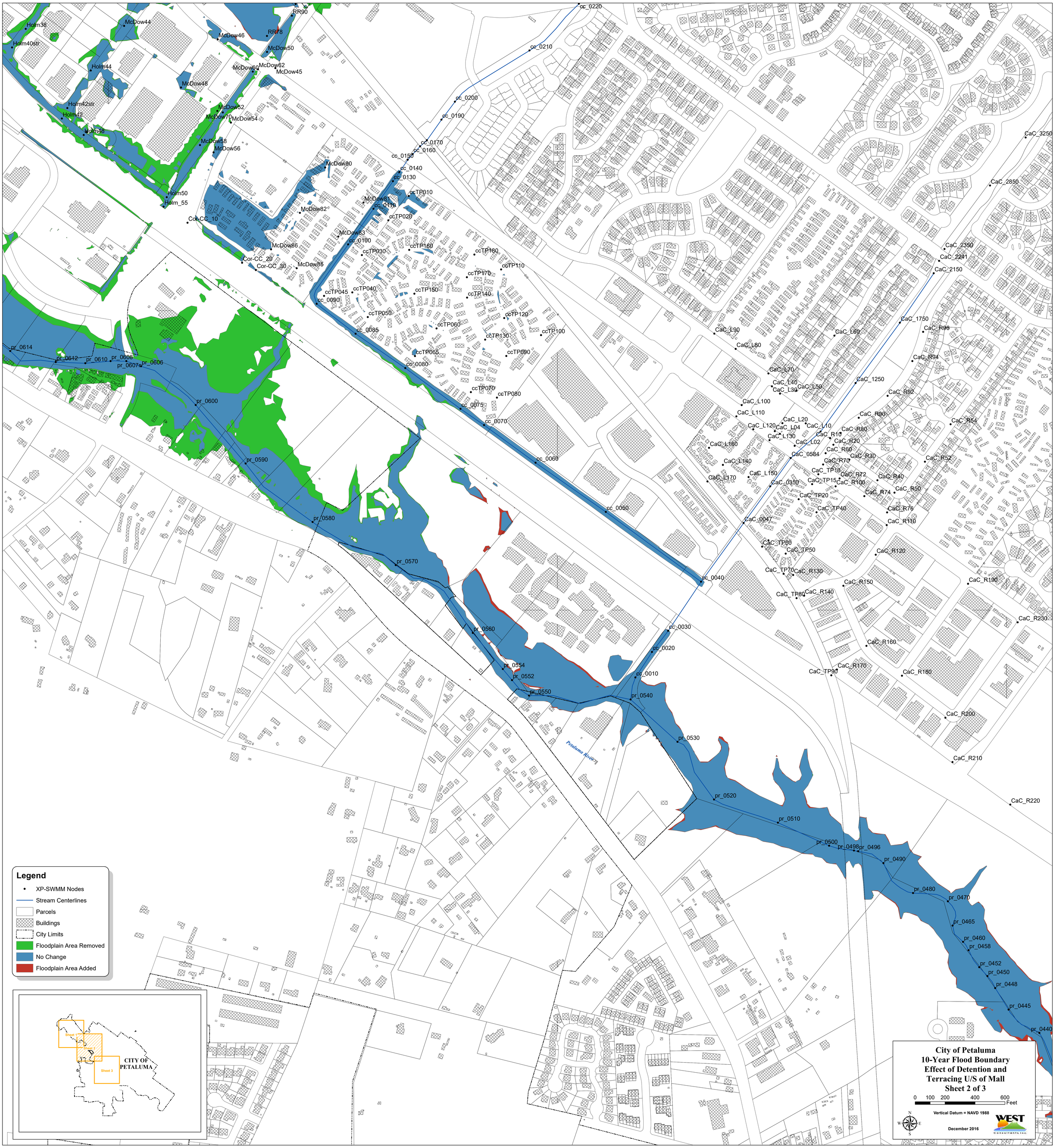
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McDow45
Holm44
McDow48
cc_0200
Holm42str
McDow52
McDow70
McDow54
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Holm42
Holm48
McDow58
McDow56
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cc_0160
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McDow80
cc_0140
cc_0130
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Holm50
Holm_55
McDow81
cc_0110
McDow82
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McDow83
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CaC_R96
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pr_0608
pr_0607
pr_0606
ccTP065
ccTP090
CaC_R94
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CaC_R60
CaC_0584
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Legend
XP-SWMM Nodes
Stream Centerlines
Parcels
Buildings
City Limits
Floodplain Area Removed
No Change
Floodplain Area Added
Sheet 1
Sheet 2
Sheet 3
CITY OF PETALUMA
City of Petaluma
10-Year Flood Boundary
Effect of Detention and
Terracing U/S of Mall
Sheet 2 of 3
0 100 200 400 600
Feet
Vertical Datum = NAVD 1988
December 2016
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Consultants, Inc.

pr_0460 pr_0458 pr_0452 pr_0450 pr_0448 pr_0445 pr_0440 pr_0420 pr_0400 pr_0430 pr_0390 pr_0380 pr_0370 pr_0360 pr_0350 pr_0340 pr_0338 pr_0330 pr_0320 pr_0310 pr_0308 pr_0300 pr_0298 pr_0290 pr_0280 pr_0260 pr_0240 pr_0230 pr_0220 pr_0210 pr_0208 pr_0206 pr_0200 pr_0195 pr_0190 pr_0180 pr_0170

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wa260R70

Pond34 Pond42 Pond44 LynchStor

Payran390L Payran390R Payran_wa Payran360

G74 G66 G70 G80 G68 G62

Legend

- XP-SWMM Nodes
- Stream Centerlines
- Parcels
- Buildings
- City Limits
- Floodplain Area Removed
- No Change
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Sheet 1
Sheet 2
Sheet 3
CITY OF PETALUMA

City of Petaluma
10-Year Flood Boundary
Effect of Detention and Terracing U/S of Mall
Sheet 3 of 3

0 100 200 400 600 Feet

Vertical Datum = NAVD 1988

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wb_2472
Red70
RR25
Red30
Red32
RR28
wb_2400
wb_1750
wb_2350
Red75
BusStor
RR30
pc_1525
REDWOOD WAY
Red65
Red40
wb_1350
Red68
wb_1348
RR40
wb_1346
wb_1344
pc_800
Red90
Red50
wb_750
RedStor
Red80
McDow08
Red52
McDow10
Red54
pc_450
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McDow20
wb_0340
Holm02
RR50
pr_0760
Holm04
Holm06
McDow22
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McDow24
RR60
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RR62
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RR78
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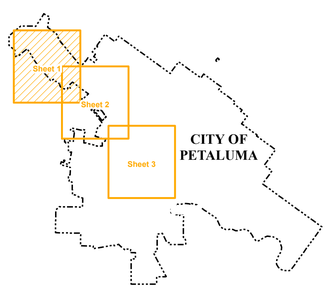
Legend

- XP-SWMM Nodes
- Stream Centerlines
- Parcels
- Buildings
- City Limits
- Floodplain Area Removed
- No Change
- Floodplain Area Added



City of Petaluma
10-Year Flood Boundary
Effect of Terracing
Sheet 1 of 3

0 100 200 400 600 Feet

Vertical Datum = NAVD 1988

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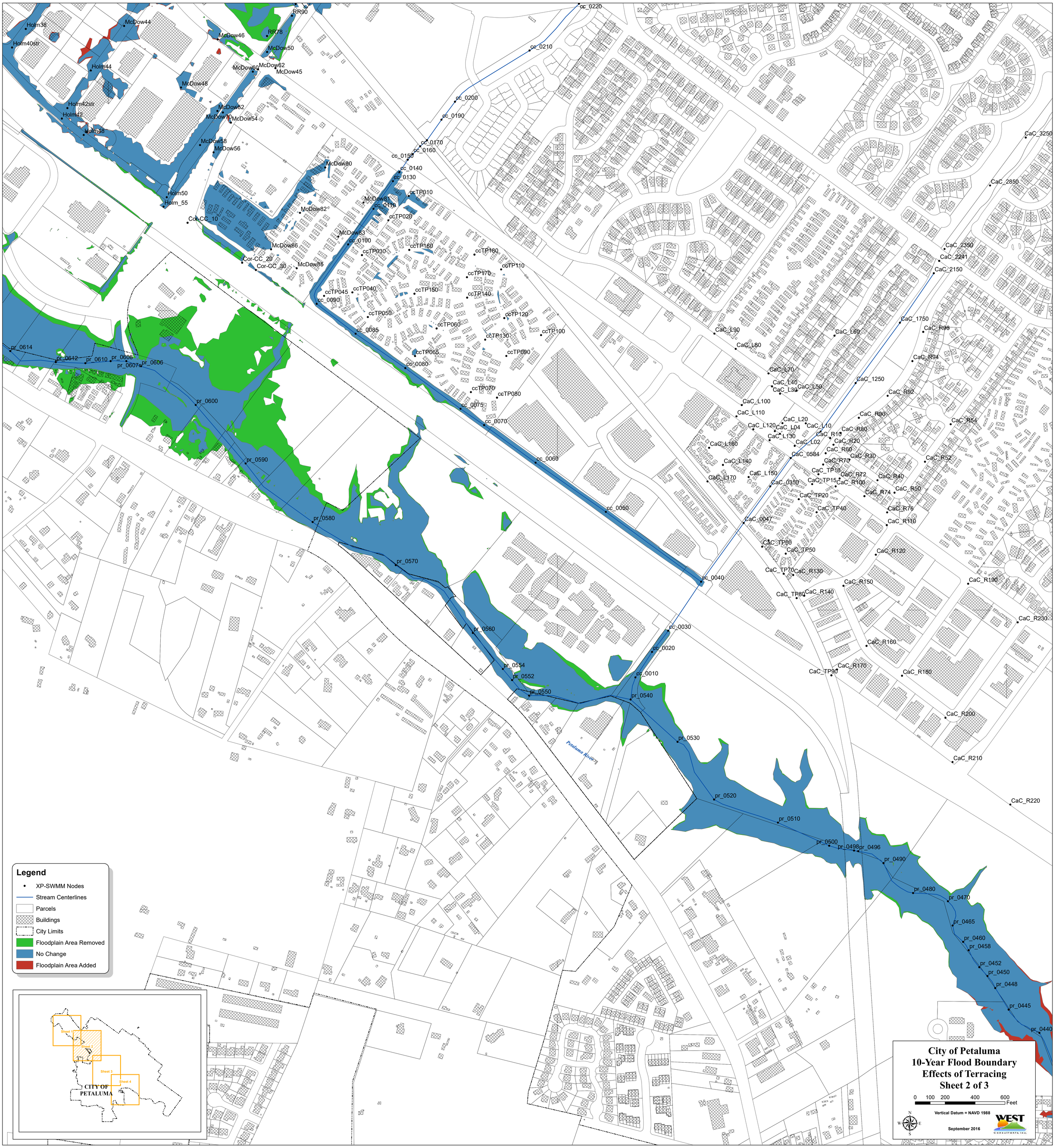
September 2016

WEST Consultants, Inc.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Holm42str
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McDow82
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McDow83
McDow86
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CaC_1750
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CaC_R220
Petaluma River
Legend
XP-SWMM Nodes
Stream Centerlines
Parcels
Buildings
City Limits
Floodplain Area Removed
No Change
Floodplain Area Added
Sheet 1
Sheet 2
Sheet 3
Sheet 4
CITY OF PETALUMA
City of Petaluma
10-Year Flood Boundary
Effects of Terracing
Sheet 2 of 3
0 100 200 400 600
Feet
Vertical Datum = NAVD 1988
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September 2016
WEST Consultants, Inc.

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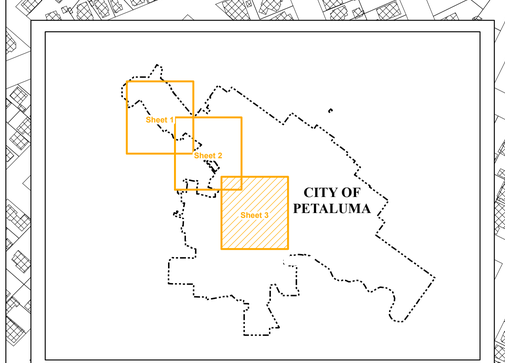

Legend

- XP-SWMM Nodes
- Stream Centerlines
- Parcels
- Buildings
- City Limits
- Floodplain Area Removed
- No Change
- Floodplain Area Added

City of Petaluma
10-Year Flood Boundary
Effect of Terracing
Sheet 3 of 3

0 100 200 400 600 Feet

Vertical Datum = NAVD 1988

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Appendix 2

100-year Event Flood Boundary Graphics

wb_2472
Red70
wb_2400
wb_1750
wb_2350
Red75
BusStor
RR25
Red30
Red32
RR28
RR30
REDWOOD WAY
Red40
Red65
Red68
RR40
pc_1525
wb_1350
wb_1348
wb_1346
wb_1344
pc_800
Red90
Red50
wb_750
RedStor
Red80
McDow08
Red52
McDow10
Red54
pc_450
wb_350
McDow20
wb_0340
Holm02
RR50
pr_0760
Holm04
Holm06
McDow22
Red_100
Holm08
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RR60
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Holm14
McDow26
RR64
Holm16
McDow30
pr_0745
pr_0740
Holm22
pr_0730
pr_0725
pr_0723
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McDow35
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RR70
Holm25
Holm_22
Holm27
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Legend

- XP-SWMM Nodes
- Stream Centerlines
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- City Limits
- Floodplain Area Removed
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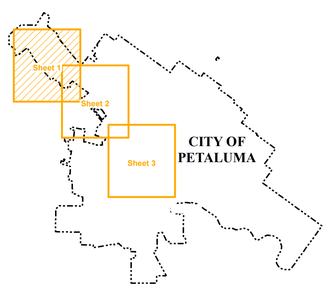

City of Petaluma
100-Year Flood Boundary
Effect of Detention
Sheet 1 of 3

0 100 200 400 600 Feet

Vertical Datum = NAVD 1988

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City of Petaluma
100-Year Flood Boundary
Effect of Detention
Sheet 2 of 3

0 100 200 400 600 Feet

Vertical Datum = NAVD 1988

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WEST Consultants, Inc.

Legend

- XP-SWMM Nodes
- Stream Centerlines
- Parcels
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- City Limits
- Floodplain Area Removed
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CITY OF PETALUMA

Sheet 1
Sheet 2
Sheet 3
Sheet 4

Petaluma River

pr_0460 pr_0458 pr_0452 pr_0450 pr_0448 pr_0445 pr_0440 pr_0420 pr_0400 pr_0430 pr_0390 pr_0380 pr_0370 pr_0360 pr_0350 pr_0340 pr_0338 pr_0330 pr_0320 pr_0310 pr_0308 pr_0300 pr_0298 pr_0290 pr_0280 pr_0260 pr_0240 pr_0230 pr_0220 pr_0210 pr_0208 pr_0206 pr_0200 pr_0195 pr_0190 pr_0180 pr_0170

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wa260R70

Pond34 Pond42 Pond44 LynchStor

Payran390L Payran390R Payran_wa Payran360

G74 G66 G70 G80 G68 G62

Legend

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- Stream Centerlines
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- Buildings
- City Limits
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Sheet 1 Sheet 2 Sheet 3 Sheet 4

CITY OF PETALUMA

City of Petaluma
100-Year Flood Boundary
Effect of Detention
Sheet 3 of 3

0 100 200 400 600 Feet

Vertical Datum = NAVD 1988

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September 2016

WEST Consultants, Inc.

wb_2472
Red70
wb_2400
wb_1750
wb_2350
Red75
BusStor
RR25
Red30
Red32
RR28
RR30
REDWOOD WAY
Red40
Red65
Red68
RR40
pc_1525
wb_1350
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pc_800
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RedStor
Red80
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McDow10
Red54
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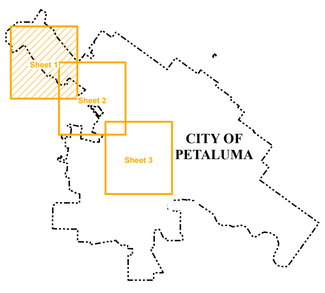
RR80
pr_0680
RR90
McDow44
pr_0670
Holm38
RR78
McDow46
Holm40str
McDow50
Holm40
McDow62
McDow60
McDow45
Holm44
pr_0660
McDow48
Holm42str
McDow52
pr_0650
Holm42
McDow70
McDow54
pr_0640
Holm48
McDow58
McDow56
pr_0630
Holm50
Holm_55
Cor-CC_10
McDow86
pr_0620
Cor-CC_20
Cor-CC_30
pr_0618
pr_0616
pr_0614
pr_0612
pr_0610
pr_0608
pr_0607
pr_0606
pr_0600
pr_0590

Legend

- XP-SWMM Nodes
- Stream Centerlines
- Parcels
- Buildings
- City Limits
- Floodplain Area Removed
- No Change
- Floodplain Area Added



City of Petaluma
100-Year Flood Boundary
Effect of Detention/Terracing
Sheet 1 of 3

0 100 200 400 600 Feet

Vertical Datum = NAVD 1988

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Holm38
McDow44
RR90
RR78
McDow46
Holm40str
McDow50
Holm44
McDow60
McDow62
McDow45
McDow48
Holm42str
McDow52
Holm42
McDow70
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Holm48
McDow58
McDow56
McDow80
Holm50
Holm_55
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McDow82
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McDow83
McDow86
Cor-CC_20
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McDow85
pr_0614
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CaC_R60
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CaC_R170
CaC_R180
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CaC_R220
Petaluma River
Legend
XP-SWMM Nodes
Stream Centerlines
Parcels
Buildings
City Limits
Floodplain Area Removed
No Change
Floodplain Area Added
Sheet 1
Sheet 2
Sheet 3
Sheet 4
CITY OF PETALUMA
City of Petaluma
100-Year Flood Boundary
Effect of Detention/Terracing
Sheet 2 of 3
0 100 200 400 600 Feet
Vertical Datum = NAVD 1988
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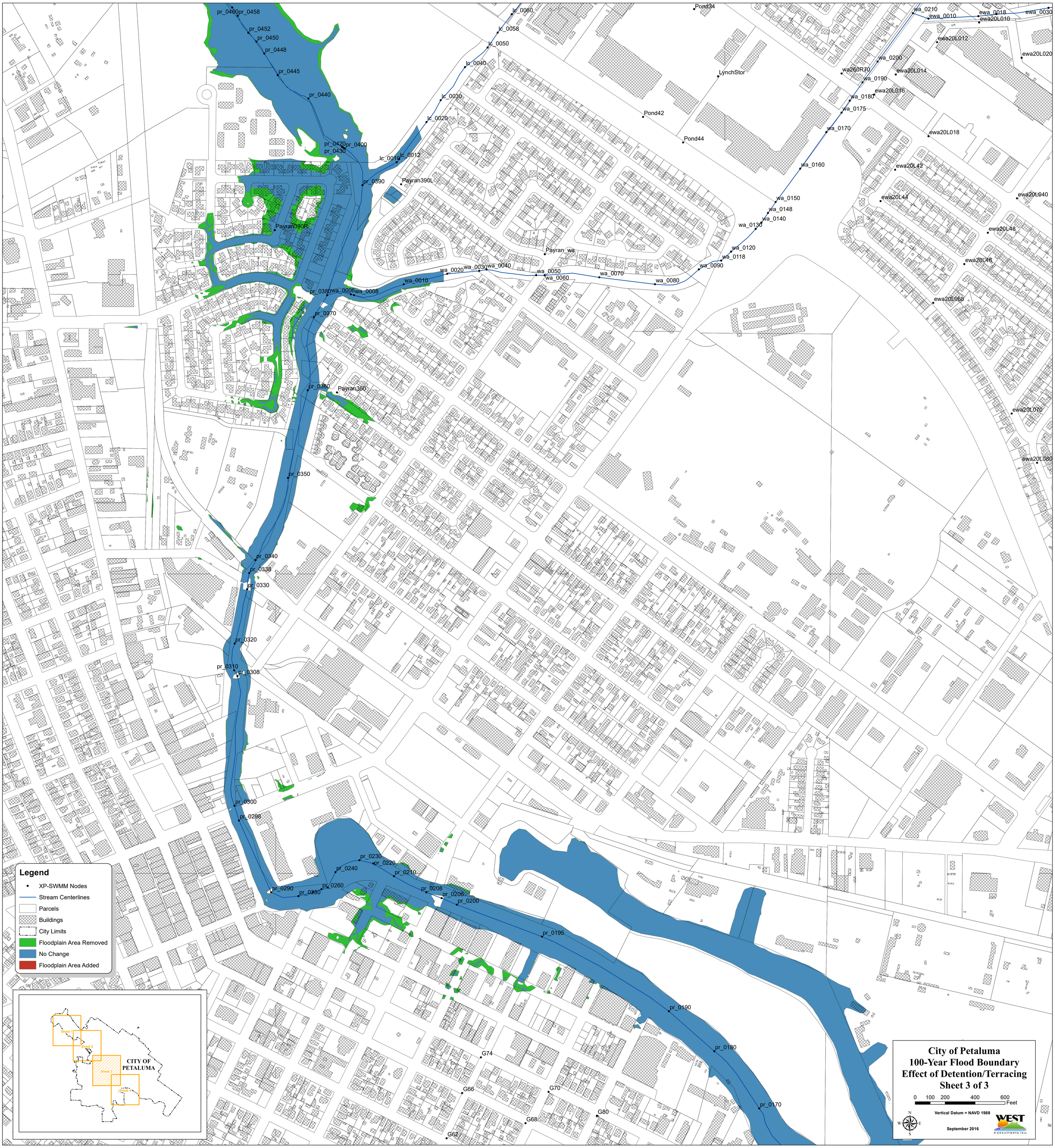
September 2016
WEST Consultants, Inc.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pr_0390
Payran390L
Payran390R
pr_0380
wa_0006
wa_0008
pr_0370
pr_0360
Payran360
pr_0350
pr_0340
pr_0338
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pr_0320
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pr_0300
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pr_0290
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pr_0240
pr_0230
pr_0220
pr_0210
pr_0208
pr_0206
pr_0200
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pr_0180
pr_0170
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lc_0058
lc_0050
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lc_0030
lc_0020
lc_0010
lc_0012
Pond34
Pond42
Pond44
LynchStor
wa_0210
ewa_0018
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Legend
XP-SWMM Nodes
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CITY OF PETALUMA
City of Petaluma
100-Year Flood Boundary
Effect of Detention/Terracing
Sheet 3 of 3
0 100 200 400 600 Feet
Vertical Datum = NAVD 1988
September 2016
WEST consultants inc.

wb_2472
Red70
wb_2400
wb_1750
wb_2350
Red75
BusStor
RR25
Red30
Red32
RR28
RR30
REDWOOD WAY
Red40
Red65
Red68
RR40
pc_1525
wb_1350
wb_1348
wb_1346
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Red90
Red50
pc_800
wb_750
RedStor
Red80
McDow08
Red52
McDow10
Red54
pc_450
wb_350
McDow20
wb_0340
Holm02
RR50
pr_0760
Holm04
Holm06
McDow22
Red_100
Holm08
McDow24
RR60
Holm10
RR62
pr_0750
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Holm12
Holm17
Holm14
McDow26
RR64
Holm16
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Holm20
McDow35
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Holm24
RR70
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Holm_22
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pr_0600
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Legend

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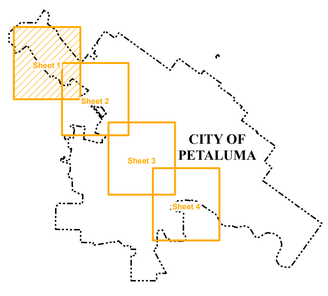

City of Petaluma
100-Year Flood Boundary
Effect of Detention and Terracing U/S of Mall
Sheet 1 of 3

0 100 200 400 600 Feet

Vertical Datum = NAVD 1988

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City of Petaluma
100-Year Flood Boundary
Effect of Detention and Terracing U/S of Mall
Sheet 2 of 3

0 100 200 400 600 Feet

Vertical Datum = NAVD 1988

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Legend

- XP-SWMM Nodes
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CITY OF PETALUMA

Sheet 1
Sheet 2
Sheet 3
Sheet 4

Petaluma River

RR90 RR78
Holm38 Holm40str Holm44 Holm42str Holm42 Holm48 Holm50 Holm_55
McDow44 McDow46 McDow50 McDow60 McDow62 McDow45 McDow48 McDow52 McDow70 McDow54 McDow58 McDow56 McDow80 McDow81 McDow82 McDow83 McDow86 McDow85
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CaC_L90 CaC_L80 CaC_L70 CaC_L60 CaC_L40 CaC_L30 CaC_L50 CaC_L100 CaC_L110 CaC_L120 CaC_L04 CaC_L20 CaC_L10 CaC_L130 CaC_L02 CaC_L160 CaC_L140 CaC_L150 CaC_L170
CaC_R96 CaC_R94 CaC_R92 CaC_R90 CaC_R54 CaC_R80 CaC_R10 CaC_R20 CaC_R60 CaC_R30 CaC_R52 CaC_R70 CaC_R72 CaC_R40 CaC_R100 CaC_R74 CaC_R50 CaC_R76 CaC_R110 CaC_R120 CaC_R130 CaC_R140 CaC_R150 CaC_R190 CaC_R230 CaC_R160 CaC_R170 CaC_R180 CaC_R200 CaC_R210 CaC_R220
CaC_0584 CaC_0350 CaC_0047
CaC_TP10 CaC_TP15 CaC_TP20 CaC_TP40 CaC_TP60 CaC_TP50 CaC_TP70 CaC_TP80 CaC_TP90

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lc_0060 lc_0058 lc_0050 lc_0040 lc_0030 lc_0020 lc_0012 lc_0010

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Pond34 LynchStor Pond42 Pond44 Payran390L Payran390R Payran_wa Payran360

G74 G66 G70 G68 G80 G62

Legend

- XP-SWMM Nodes
- Stream Centerlines
- Parcels
- Buildings
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- Floodplain Area Removed
- No Change
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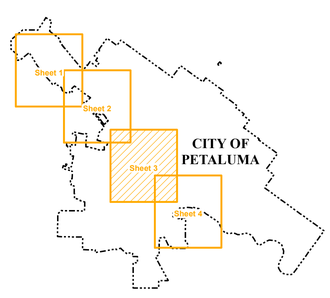

City of Petaluma
100-Year Flood Boundary
Effect of Detention and Terracing U/S of Mall
Sheet 3 of 3

0 100 200 400 600 Feet

Vertical Datum = NAVD 1988

N W E S

December 2016

WEST consultants inc.

REDWOOD WAY

Legend

- XP-SWMM Nodes
- Stream Centerlines
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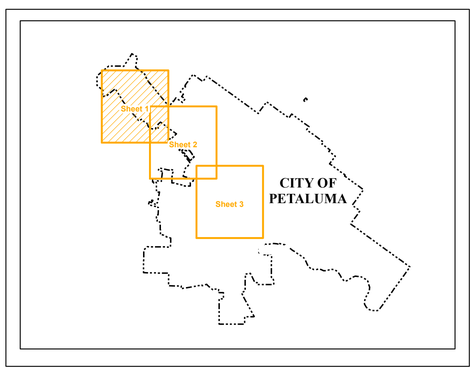

City of Petaluma
100-Year Flood Boundary
Effect of Terracing
Sheet 1 of 3

0 100 200 400 600 Feet

Vertical Datum = NAVD 1988

N W E S

September 2016

WEST Consultants, Inc.

Holm38
McDow44
RR90
cc_0220
Holm40str
RR78
McDow46
cc_0210
McDow50
Holm44
McDow60
McDow62
McDow45
McDow48
cc_0200
Holm42str
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Holm42
McDow70
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Holm48
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McDow82
Cor-CC_10
ccTP020
McDow83
cc_0100
CaC_2350
McDow86
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ccTP180
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Cor-CC_20
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Cor-CC_30
McDow85
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ccTP150
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Petaluma River
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Legend

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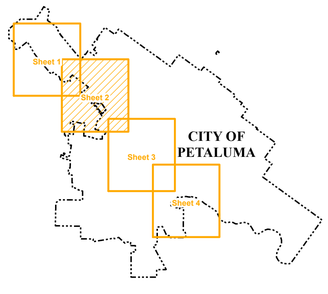

City of Petaluma
100-Year Flood Boundary
Effect of Terracing
Sheet 2 of 3

0 100 200 400 600 Feet

Vertical Datum = NAVD 1988

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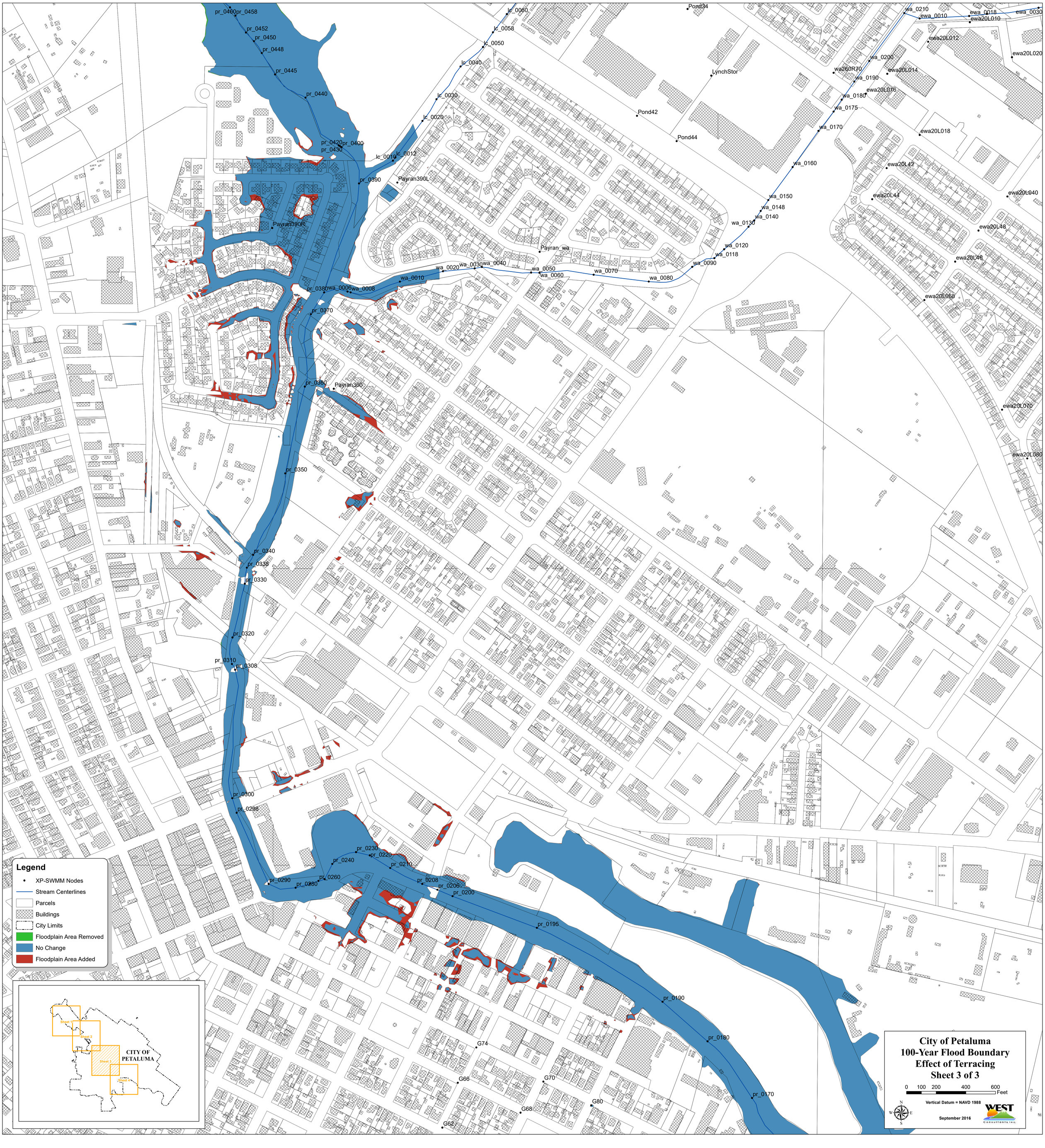
September 2016

WEST Consultants, Inc.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Pond42
Pond44
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Payran390R
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Legend
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Floodplain Area Removed
No Change
Floodplain Area Added
Sheet 1
Sheet 2
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CITY OF PETALUMA
City of Petaluma
100-Year Flood Boundary
Effect of Terracing
Sheet 3 of 3
0 100 200 400 600
Feet
Vertical Datum = NAVD 1988
September 2016
WEST
Consultants, Inc.

Exhibit 1

2007 Detention and Terracing Memo

WEST CONSULTANTS, INC.

MEMORANDUM

Project:	City of Petaluma XP-SWMM Modeling
Subject:	XP-SWMM Model Runs for Floodplain Terraces and Detention Evaluation
Date:	February 2, 2007
To:	Dean Eckerson, P.E., City of Petaluma
From:	David S. Smith, P.E., WEST Consultants, Inc.

DRAFT

This memo summarizes the analysis completed by WEST Consultants, Inc. (WEST) for the City of Petaluma (the City) to provide XP-SWMM model runs and flood boundary maps depicting the combined effect of conceptual floodplain terraces on the Petaluma River and detention basins in the Petaluma River watershed.

Floodplain Terraces

Cross sections were revised to incorporate the terracing concept based on edits provided by the City. Affected cross sections are shown in Attachment 1. Each cross section graphic includes three lines:

- Dark blue – The cross section shape and elevation at the upstream end of the reach (based on the upstream node invert elevation)
- Magenta – The cross section shape and elevation at the downstream end of the reach (based on the downstream node invert elevation)
- Cyan – The shape of the cross section used in XP-SWMM representing the terracing concept.

The existing floodplain terraces between nodes pr_0606n (Corona Road) to pr_0618n have already been included in the existing conditions XP-SWMM model. Terraces were added upstream of the existing terraced reach from node pr_0618 to pr_0760 (confluence with Willow Brook Creek), and downstream from node pr_0606n (Corona Road) to pr_0430 (Corps weir).

Downstream of Corona Road, Manning's *n* values in the channel, 0.1 from node pr_0606n (Corona Road) to node pr_0590, were reduced to 0.05 to reflect partial vegetation clearing. Similarly, channel *n* values of 0.08 from pr_0590 to node pr_0490 (the railroad trestle bridge) were reduced to 0.05.

Detention

The following detention basin concepts were provided by the City for inclusion in the XP-SWMM model:

1) Offline detention of Willow Brook Creek upstream of the railroad crossing totaling 202.5 acre-feet (5 feet deep over 40.5 acres). This detention basin is represented in XP-SWMM as node det_1 (see Figure 1). The inlet to the basin was modeled as a 5' x 20' box culvert, 400 feet long on a 2.33% slope. The upstream end of the culvert was set 5.3 feet higher than the existing channel invert elevation with the intent of capturing the flood peak. The basin outlet was modeled as a 3' x 3' box culvert, 1000 feet long on a 1% slope.

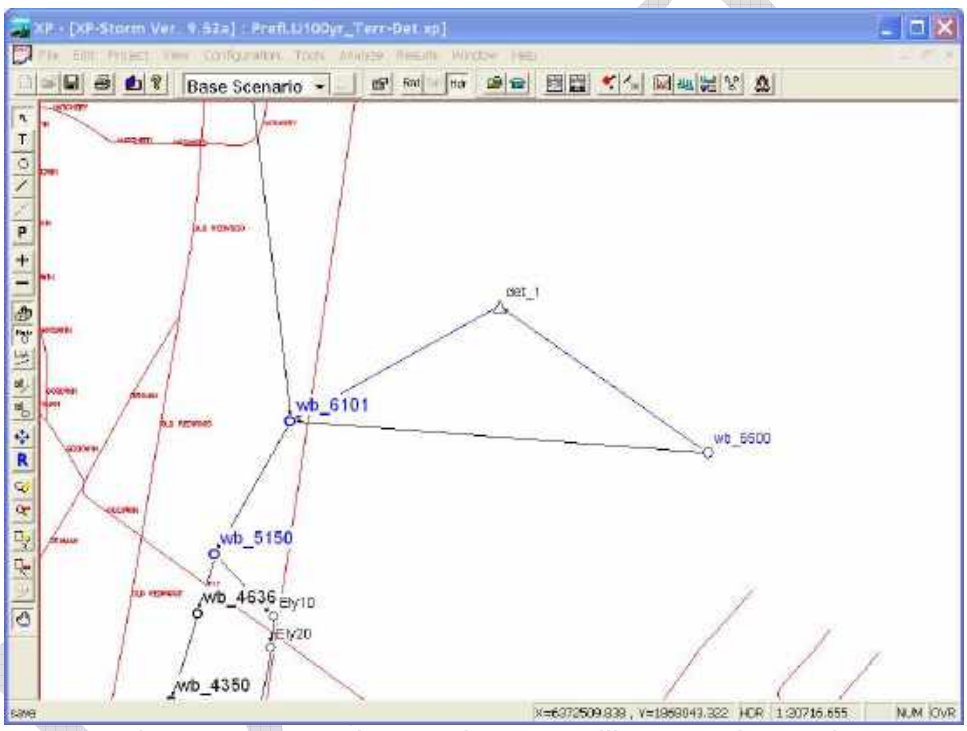

Figure 1. Detention Basin 1 on Willow Brook Creek.

2) Offline detention of Lichau Creek downstream of Petaluma Hill Road totaling 238 acre-feet (5 feet deep over 47.6 acres). This detention basin is represented in XP-SWMM as node det_2 (see Figure 2). The inlet to the basin was modeled as a 5' x 23' box culvert, 964 feet long on a 1.92% slope. The upstream end of the culvert was set 2.55 feet higher than the existing channel invert elevation with the intent of capturing the flood peak. The basin outlet was modeled as a 3-foot diameter pipe, 3000 feet long on a 1% slope.

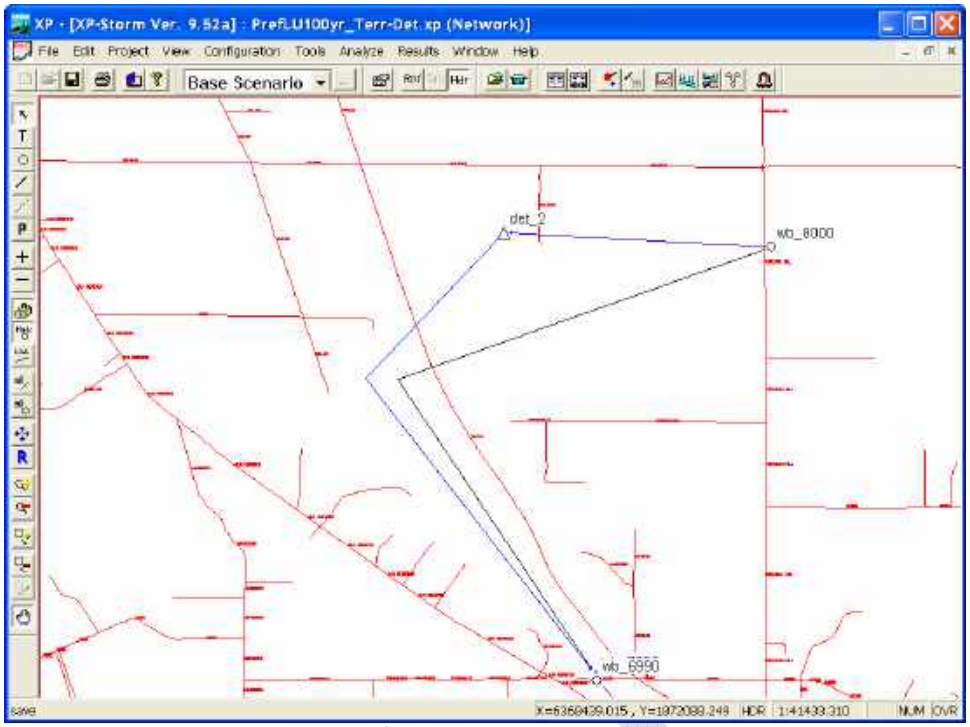

Figure 2. Detention Basin 2 on Lichau Creek.

3) Two parallel detention basins in the vicinity of the "railroad ditch" between Willow Brook Creek and Corona Road. These detention basins are represented in XP-SWMM as nodes det_3a and det_3b (see Figure 3).

    a. Basin 1 – Offline detention for flow into the railroad ditch originating from Willow Brook Creek totaling 23 acre-feet (5 feet deep over 4.6 acres) The inlet to the basin was modeled as a 3' x 6' box culvert, 239 feet long on a 2% slope. The upstream end of the culvert was set at the grade of the existing invert with the intent of capturing as much of the breakout flow as possible. The basin outlet was modeled as a 3' x 6.5' box culvert, 586 feet long on a 1% slope.
    b. Basin 2 – Inline detention for watershed runoff to the railroad ditch from the northeast totaling 23 acre-feet (same size as and parallel to Basin 1). No constraint was modeled at the inlet to the basin, but all upstream flow is assumed to be routed to the basin. The basin outlet was modeled as a 3' x 3' box culvert, 586 feet long on a 1% slope.

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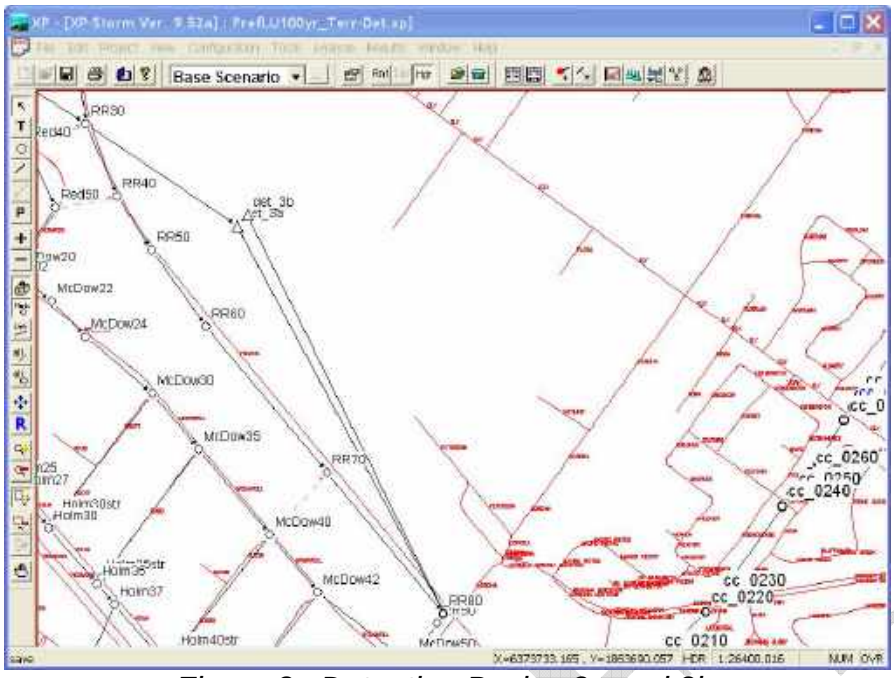

Figure 3. Detention Basins 3a and 3b.

4) Offline detention of the Petaluma River in the vicinity of Bailey Road totaling 150 acre-feet (5 feet deep over 30 acres). This detention basin is represented in XP-SWMM as node det_4 (see Figure 4). The inlet to the basin was modeled as a 3' x 10' box culvert, 333 feet long on a 1.62% slope. The upstream end of the culvert was set 11.53 feet higher than the existing channel invert elevation with the intent of capturing the flood peak. The basin outlet was modeled as a 3-foot diameter pipe, 1000 feet long on a 1% slope.

5) Excavation of a portion of the Benson property to provide additional detention (approximately 15 acre-feet). This detention basin is represented in XP-SWMM as node StonyStor in Figure 5. A 3 foot diameter pipe was added to the model that would drain the Benson property to the confluence of Willow Brook Creek and the Petaluma River (in addition to the two existing culverts connecting the Benson property with Petaluma Creek). The pipe was modeled as 200 feet long on a 1% slope, and it was assumed to have a flap gate to prevent reverse flow.

6) Excavation of the Hummel property to provide additional detention (approximately 24 acre-feet) and redirection of flow entering the west side of the property to drain back to Willow Brook Creek. These detention basins are represented in XP-SWMM as nodes DenmanStor (Hummel_a) and Hummel_b in Figure 5.

    a. 90% of the Hummel property storage volume was connected by weir flow to Willow Brook Creek and by culvert to the Benson

property. The additional detention volume of 24 acre-feet was applied to this location.

b. 10% of the Hummel property storage volume was connected to the N. McDowell extension overflow. The outlet for the flows redirected back to Willow Brook Creek with a flap gate to prevent reverse flow was modeled as a 2 foot diameter pipe, 300 feet long on a 1.4% slope.

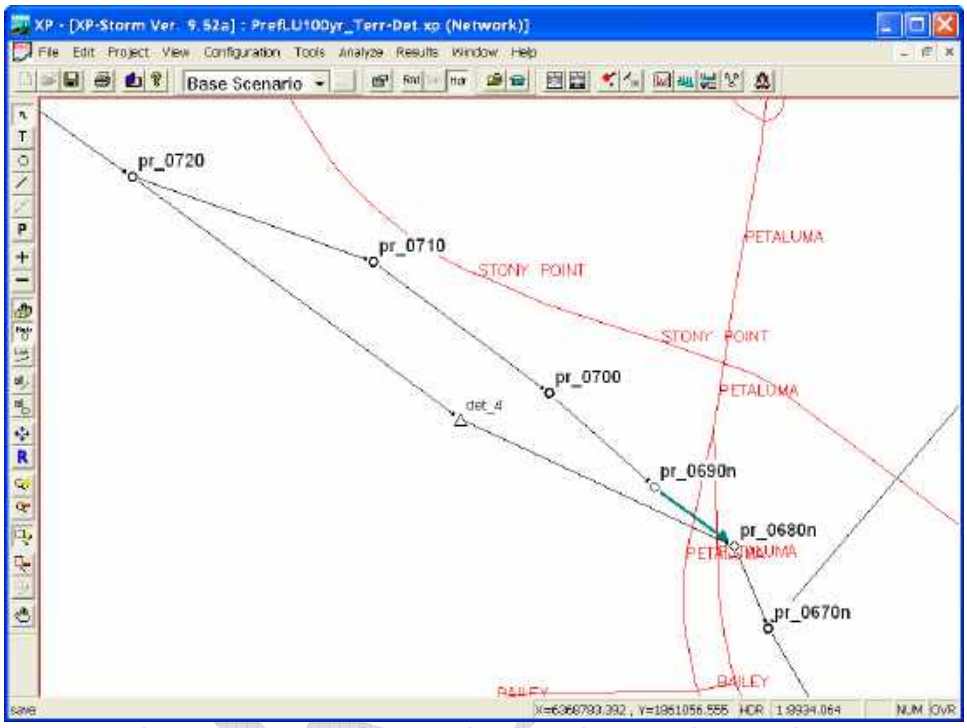

Figure 4. Detention Basin 4 on the Petaluma River.

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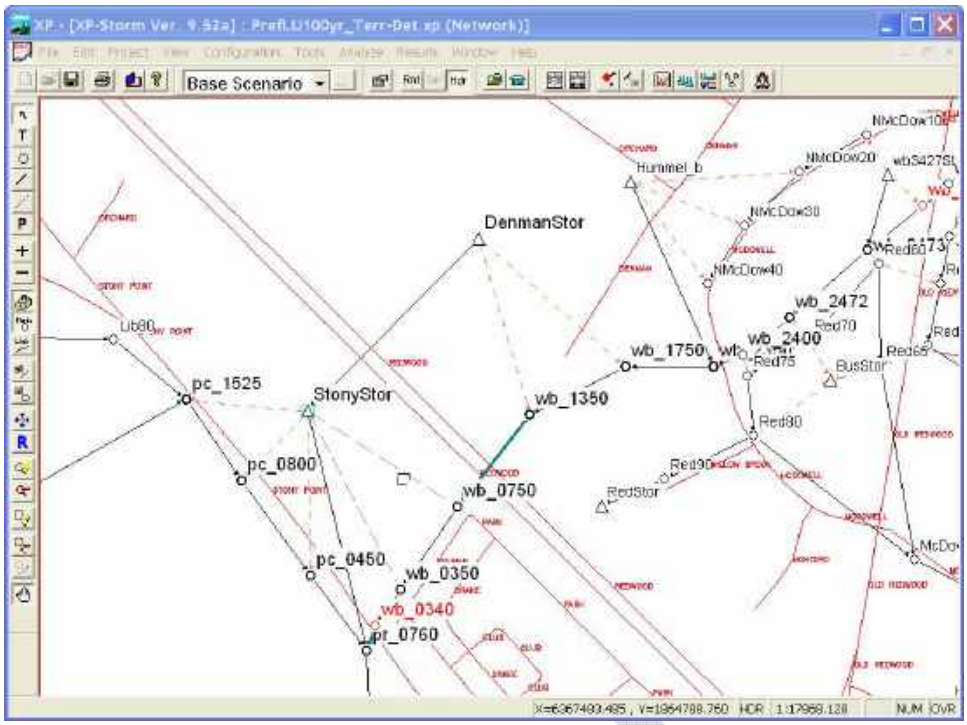

Figure 5. Detention Basins StonyStor (Benson), Denman Stor (Hummel_a), and Hummel_b.

Approach

The 10-, 25-, 50-, and 100-year rainfall events were used to evaluate the effectiveness of the proposed terracing and detention projects. The inlet/outlet capacities of the detention basins and the elevation of the inlet were determined by trial and error to maximize detention basin storage for the 100-year storm simulation. Less detention is expected for events smaller than the 100-year storm because only the top portion of the hydrograph will be detained.

Previously developed XP-SWMM models by WEST were extended upstream in the Lichau and Willow Brook Creek watersheds to incorporate the detention concepts. The Lichau Creek reach was extended upstream to Petaluma Hill Road (model node wb_8000) and the Willow Brook Creek reach was extended about one-half mile upstream of the railroad grade (model node wb_5500). The hydrology was also subdivided in both areas to provide an approximate inflow at the upstream end of each hydraulics reach. After extending the model, the peak flow in Willow Brook Creek was about 300 cfs higher than the previous model results because the hydrographs were combining differently. Because the previous hydrologic configuration was calibrated to gage data, an attempt was made to adjust the extended model results in the Lichau and Willow Brook watersheds to reduce the flow by about 300 cfs. This was accomplished by removing the assumed breakout flow from the Copeland Creek watershed previously estimated as 300 cfs. With this adjustment, the flow and water surface elevation at node wb_6101 (Willow Brook Creek just upstream of Ely

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Road) match the calibrated network configuration results. The revised hydrologic parameters are summarized in Table 1.

Another change to the XP-SWMM model was moving the hydrologic inflow from node RR80 (near intersection of McDowell and Corona Rd) to node det_3b which is located parallel to the railroad grade and closer to Willow Brook Creek. This change was necessary to route the natural runoff upstream of node RR80 through the proposed detention basin, which drains to node RR80.

Results

Table 2 summarizes the flow reduction provided by each detention basin for the 100-year storm (also including the effects of flood terracing). Table 3 summarizes the amount of available storage of each detention basin that was utilized for each frequency storm event. A comparison of flood boundaries with and without the proposed terracing and detention for the 10-, 25-, 50-, and 100-year storms are provided in Figures 6 through 9, respectively.

Water surface elevation and flow reductions due to the proposed terracing and detention are summarized in Tables 4 and 5. Although not obvious in the flood boundary graphics, Tables 4 and 5 show an increase in water surface elevation and flow for the Petaluma River downstream of Lynch Creek for the 10- and 25-year storms and downstream of Washington Creek for all modeled storms. The reason for the increase seems to be related to the higher velocity due to cleared vegetation in the reach between Corona Road and Corona Creek confluence. The channel velocity increases from about 1 foot per second (fps) to 2 fps so the Petaluma River hydrograph peak reaches the Corona Creek confluence about 1 hour sooner. Because the various tributaries (Corona, Lynch, Thompson, Washington, and Adobe Creeks) combine with the rising limb of the Petaluma River hydrograph, speeding up the hydrograph in the reach downstream of Corona Road ultimately produces an increase in the peak flow by the time the Lynch and Washington Creek inflows combine with the Petaluma River peak. Downstream of Lynch Creek, although there are increases in water surface elevation and flow, the magnitude of the increases are not significant in terms of flooding impact (maximum of 3 inches in water surface elevation).

Although there are increases downstream of Lynch Creek, as described above, the proposed terracing and detention concepts produce very significant reductions in Willow Brook Creek, the Willow Creek breakout, and the Petaluma River upstream of Lynch Creek. There is a reduction of about 1,350 cfs on Willow Brook Creek, an additional 1,200 cfs for the Willow Brook breakout, and about 450 cfs on the Petaluma River. The water surface elevations are reduced 0.5 to 1.1 feet on Willow Brook Creek and 0.9 to 4.2 feet on the Petaluma River upstream of the Corona Creek confluence.

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Table 1. Revised Hydrologic Data for Lichau and Willow Brook Model Extension

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)
SCS Basin	Area (ac)	Weighted Manning n	L (ft)	L_c (ft)	L (mi)	L_c (mi)	U/S Elev (ft)	D/S Elev (ft)	S (ft/mi)	S (ft/ft)	Lag (h)	Lag (min)	T_c (min)
wb5500	2758.5	0.030	32300	11400	6.117	2.159	1610	54	254.4	0.0482	0.67	40.2	52.2
wb6101	1078.0	0.030	16550	7450	3.134	1.411	265	39	72.1	0.0137	0.56	33.7	43.8
wb7000	2665.9	0.030	21100	14800	3.996	2.803	389	57	83.1	0.0157	0.78	46.7	60.7
wb8000	2201.6	0.030	26350	11700	4.991	2.216	2140	116	405.6	0.0768	0.57	34.4	44.7

Column

(1) SCS Node ID

(2) Subbasin area in acres

(3) Weighted Manning's n = the average of the Manning's n values of the watercourse and its tributaries

(4) L = length of longest watercourse in feet

(5) L_c = length along longest watercourse, measured upstream to a point opposite the watershed centroid in feet

(6) Column (3) converted to miles

(7) Column (4) converted to miles

(8) Elevation of highest point in catchment

(9) Elevation of catchment outlet

(10) Overall slope between the headwaters and the collection point in feet per mile

(11) Effective catchment slope, ft/ft

(12) Lag in hours = $24*(\text{Weighted Manning n})*((L * L_c)/S^{0.5})^{0.38}$, where slope is from Column (9) and lengths from Columns (5) and (6)

(13) Lag in minutes

(14) Time of concentration is computed by combining the lag relationship with time to peak ($lag=1.16*T_p$) and the time of concentration relationship with time to peak ($T_p = 0.67*T_c$), such that $lag = 1.16*(0.67*T_c) = 0.77*T_c$. Therefore, T_c = (lag in minutes)/0.77

Table 2. 100-year Detention Results Summary

Basin Number	Location	Inlet		Outlet		Maximum Depth in Basin[1]
		From	Peak Flow (cfs)[2]	To	Peak Flow (cfs)[3]	
1	Willow Brook	Willow Brook Creek	868	Willow Brook Creek / Lichau Creek confluence	85	5.1
2	Lichau	Lichau Creek	580	Lichau Creek	72	4.9
3a	RR ditch (Northeast inflows)	RR ditch	298	RR ditch / N. Corona Channel confluence	190	4.7
3b	RR ditch (Willow Brook overflows)	watershed	227	RR ditch / N. Corona Channel confluence	89	4.8
4	Bailey Rd	Petaluma River	349	Petaluma River	52	5.1
5	Benson	Petaluma Creek by weir and culvert; Hummel property	1220	Petaluma River / Willow Brook Creek confluence by culvert; Hummel property	75	9.7
6a	Hummel (a)	Willow Brook Creek by weir; Benson property	765	Willow Brook Creek by weir; Benson property	89	5.3
6b	Hummel (b)	N. McDowell extention overflows	23	Willow Brook Creek by culvert	5	0.5

Notes:

1) Basins 1 - 4 are modeled as approximately 5 feet deep
2) Peak inflows to the Benson and Hummel properties are approximated at the simulation time with the largest inflow
3) Peak outflows from the Benson and Hummel properties are approximated at the simulation time with the largest outflow

Table 3. Detention Storage Usage By Storm Event Frequency

Basin Number	Location	Available Storage[2] (ac-ft)	100-year		50-year		25-year		10-year	
			Maximum Storage Volume (ac-ft)	Percentage of Available Storage Used[1]	Maximum Storage Volume (ac-ft)	Percentage of Available Storage Used[1]	Maximum Storage Volume (ac-ft)	Percentage of Available Storage Used[1]	Maximum Storage Volume (ac-ft)	Percentage of Available Storage Used[1]
1	Willow Brook	202.5	205.5	101	167.6	83	127.0	63	76.7	38
2	Lichau	238	231.4	97	189.1	79	148.6	62	103.8	44
3a	RR ditch (Northeast inflows)	23	21.8	95	19.7	85	14.2	62	5.5	24
3b	RR ditch (Willow Brook overflows)	23	22.0	96	17.8	77	13.9	61	10.3	45
4	Bailey Rd	150	153.0	102	112.1	75	78.1	52	34.5	23
5	Benson	100	104.6	105	97.1	97	84.5	85	64.1	64
6a	Hummel (a)	90	99.3	110	82.3	91	51.1	57	19.8	22
6b	Hummel (b)	13.8	0.8	6	0.0	n/a[3]	0.0	n/a[3]	0.0	n/a[3]

Notes:

1) Value greater than 100% indicates maximum capacity exceeded or weir flow out of basin
2) Available storage of Benson and Hummel (a) was approximated as the detention basin volume below an average top of bank elevation.
3) No breakout flow occurs in the N. McDowell extension for these events, so no storage was modeled in Hummel (b)

Table 4. Water Surface Elevation Reduction at Key Locations with Terraces/Detention Concept

Location	Model Node	100-year		50-year		25-year		10-year	
		WSEL (ft)	Reduction (ft)	WSEL (ft)	Reduction (ft)	WSEL (ft)	Reduction (ft)	WSEL (ft)	Reduction (ft)
Willow Brook Creek upstream of Ely Road	wb_6101	51.94	0.88	51.54	0.92	51.25	0.85	50.81	0.71
Willow Brook Creek upstream of Old Redwood Highway	wb_3427	44.21	0.49	43.84	0.65	43.31	0.96	42.85	0.89
Willow Brook Creek upstream of McDowell	wb_2400	41.61	0.57	41.37	0.58	41.03	0.65	40.63	0.67
Willow Brook Creek upstream of Stony Point Rd	wb_0340	38.97	1.08	38.43	1.07	38.17	0.79	37.59	0.69
Willow Brook breakout to RR ditch	RR40	39.58	0.77	39.44	0.81	39.34	0.67	39.08	0.70
Willow Brook breakout to McDowell Blvd.	McDow20	36.88	1.16	36.66	1.10	36.60	0.76	36.41	0.52
Willow Brook breakout to Holm Rd. ditch	Holm16	30.87	2.86	29.58	3.91	28.50	4.45	26.59	5.07
Petaluma River upstream of Rainsville	pr_0750	38.29	0.87	37.83	0.89	37.48	0.88	36.74	0.91
Petaluma River upstream of Petaluma Blvd (twin bridges)	pr_0700	34.51	0.97	33.82	1.39	33.39	1.43	32.60	1.49
Petaluma River upstream of Corona Road	pr_0608n	28.10	4.07	27.54	4.15	27.03	4.11	26.30	3.92
Corona Creek parallel to Petaluma River	cc_0080	26.04	1.86	25.75	1.72	25.24	1.80	24.58	1.48
Petaluma River just downstream of Corona Creek confluence	pr_0540n	21.49	4.20	20.75	4.54	20.22	4.60	19.34	4.46
Petaluma River just downstream of Corps weir	pr_0400	15.93	-0.22	14.65	-0.04	13.56	-0.12	12.45	-0.03
Petaluma River just downstream of Lynch Creek confluence	pr_0390	15.86	-0.23	14.58	-0.06	13.48	-0.14	12.35	-0.04
Petaluma River just downstream of Washington Creek confluence	pr_0380	15.61	-0.24	14.33	-0.09	13.16	-0.16	11.98	-0.05
Petaluma River just downstream of Thompson Creek confluence	pr_0195	9.23	-0.18	8.73	-0.14	8.30	-0.14	7.72	-0.10
Petaluma River just downstream of Adobe Creek confluence	pr_0040	6.77	-0.04	6.69	-0.04	6.60	-0.03	6.51	-0.02

Notes:

1) Reduction with terrace/detention (negative number indicates an increase)
2) All scenarios compared above are based on buildout conditions

Table 5. Flow Reduction at Key Locations with Terraces/Detention Concept

Location	Model Node	100-year		50-year		25-year		10-year	
		Flow (cfs)	Reduction (cfs)	Flow (cfs)	Reduction (cfs)	Flow (cfs)	Reduction (cfs)	Flow (cfs)	Reduction (cfs)
Willow Brook Creek upstream of Ely Road	wb_6101	3682	1351	3191	1264	2852	1059	2365	799
Willow Brook Creek upstream of Old Redwood Highway	wb_3427	2242	507	2053	465	1852	454	1636	384
Willow Brook Creek upstream of McDowell	wb_2400	2964	251	2790	356	2522	488	2255	499
Willow Brook Creek upstream of Stony Point Rd	wb_0340	2607	299	2347	517	2349	361	2241	105
Willow Brook breakout to RR ditch	RR40	81	42	74	41	67	32	55	39
Willow Brook breakout to McDowell Blvd.	McDow20	122	1164	30	785	18	468	1	146
Willow Brook breakout to Holm Rd. ditch	Holm16	198	230	116	242	75	194	4	201
Petaluma River upstream of Rainsville	pr_0750	6126	447	5321	1121	4872	1017	4193	174
Petaluma River upstream of Petaluma Blvd (twin bridges)	pr_0700	5777	370	5101	611	4693	410	4057	289
Petaluma River upstream of Corona Road	pr_0608n	6288	413	5510	587	4998	452	4211	303
Corona Creek parallel to Petaluma River	cc_0080	348	169	307	169	277	166	243	122
Petaluma River just downstream of Corona Creek confluence	pr_0540n	6760	440	5923	580	5368	355	4490	163
Petaluma River just downstream of Corps weir	pr_0400	6959	315	6106	430	5482	276	4553	133
Petaluma River just downstream of Lynch Creek confluence	pr_0390	7865	119	6939	216	6315	-8	5118	9
Petaluma River just downstream of Washington Creek	pr_0380	8805	-187	7722	-33	6900	-134	5527	-49
Petaluma River just downstream of Thompson Creek confluence	pr_0195	9468	-306	8365	-211	7430	-281	5991	-247
Petaluma River just downstream of Adobe Creek confluence	pr_0040	11819	-546	10670	-547	9282	-478	7596	-474

Notes:

1) Reduction with terrace/detention (negative number indicates an increase)
2) All scenarios compared above are based on buildout conditions