

# TECHNICAL MEMORANDUM

TO: Sonoma Water

PREPARED BY: Ian Jaffe, PE (Woodard & Curran), Eric Riedner, P.E. and Edward D. Ballman, P.E. (Balance Hydrologics)

REVIEWED BY: Millicent Cowley-Crawford, PE, CFM (Woodard & Curran)

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RE: Concept Screening Analysis

This technical memorandum (TM) summarizes location and concept screening and modeling completed for the Upper Petaluma River Watershed Flood Control Project Feasibility study. Hydraulic modeling was performed to estimate expected flood management benefits for various combinations of project type and location within the watershed. The hydraulic model was constructed using watershed level information in order to begin to assess projects with broader, watershed level benefits which could also be used to address localized flooding concerns. For the purposes of this TM, the term “regional” refers to, and is used interchangeably with, “watershed level.”

Flood management benefits were quantified under both 10-year and 100-year flood conditions to identify the most effective project scenarios. The relative benefits of the project concepts were used to rank alternatives based on potential watershed level benefits, with local benefits briefly reviewed and recorded for future consideration. This effort built upon work previously documented in the Model Build Report (April 2019) and Tributary Selection TM (May 2019). The evaluation presented in this TM is meant to provide guidance for a more detailed project evaluation in the next phase of this effort. The conclusions to build upon, as well as the limitations of this evaluation, are presented in the final sections of this TM.

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## 1. HYDRAULIC MODELING OVERVIEW

Existing conditions one- and two-dimensional hydraulic models were prepared under a previous phase of work. A HEC-RAS model was developed for the Upper Petaluma River Watershed and the XPStorm model for the downstream Petaluma River Watershed (around the City of Petaluma) was utilized for continuity with the 2011 FEMA Study. These models were updated to reflect ten different project configurations including two flood reduction project concepts: detention basins and floodplain modifications along five different tributaries to the Upper Petaluma River. Each project concept and tributary combination was applied in separate model scenarios in order to isolate project impacts and compare results.

The modeled tributaries included Willow Brook, Lichau, Marin, Liberty and Lynch Creeks. The rationale for selecting these tributaries is summarized in the Tributary Selection Basis TM prepared by Balance Hydrologics. In order to provide an accurate representation of the relative flood reduction benefits of projects on each tributary, each simulated detention basin and floodplain storage area was assumed to have the same size which allowed the hydraulic impacts—change in peak flow, peak water surface elevation, peak flood depth, peak velocity and overbank flood duration—to be compared for each configuration. A map of the selected tributaries (reproduced from the Tributary Selection Basis TM) is included in Figure 1.

### 1.1 Modeled Detention Basin Project Concepts

Detention basin projects were sited at hydraulically comparable locations along each tributary, as shown on Figure 2. Hydraulically comparable locations were defined as the point of concentration that includes approximately 80 percent of the total tributary sub-watershed area (consistent with the analysis included in the Tributary Selection Basis TM). Factors such as property ownership, existing land uses, and topography were not considered in siting the projects.

Detention basin concepts were simplified in the modeling to demonstrate the maximum project impact. Although it is intended for the eventual detention basins to attenuate flood flows, during this assessment, they were modeled as retention basins that captured and held a specific volume so as to avoid the process of concept refinement to properly time the release of the attenuated flow during this initial concept review. When modeled, the basins fill up until their maximum volume is reached at which point the inflow equals the outflow and the basin no longer impacts the hydrograph. These basins were located adjacent to each channel instead of in the channel itself, which is known as offline storage.

The Willow Brook, Lichau, Marin, and Liberty Creek basin simulations were all accomplished through modification of the HEC-RAS model only, while Lynch Creek modeling was done in XPStorm. The basins were each assumed to be one-dimensional storage areas with an area of 25 acres, a maximum depth of 4 feet, and a maximum storage volume of 100 acre-feet.

In the HEC-RAS modeling, flow was routed into each storage area through a channel graded into the model terrain and a storage area/2D area connector placed at the outer extent of the 2D area. The storage area/2D connector included a weir with an invert placed slightly below the 10-year water surface elevation in the adjacent tributary channel and a width set to divert 100 acre-feet of flow into the storage area during the 100-year flood event. Weir dimensions are the same for the 100- and 10-year simulations at each location. A schematic of the modeled detention basin concept is included as Figure 3.

The Lynch Creek basin was located within the XPStorm model domain and is parameterized using similar methods to those described for the HEC-RAS model. The basin is modeled using a storage node with an area of 25 acres, a maximum depth of 4 feet, and a maximum storage volume of 100 acre-feet. Flow was routed into the basin via a user-defined weir with an invert placed slightly below the 10-year water surface elevation in the adjacent channel node and a width set to divert 100 acre-feet of flow into the storage node during the 100-year flood event.

Impacts of the detention basins on model hydrographs varied by tributary with the time to fill each basin ranging from one to nine hours depending on the tributary. Model results are discussed further throughout this TM. Resulting hydrographs are included in Appendix A.

## 1.2 Modeled Floodplain Modification Project Concepts

The floodplain modification projects were placed at the same locations as the detention basin projects, as shown on Figure 2. The Willow Brook, Lichau, Marin, and Liberty Creek floodplain modification projects are all modeled in the HEC-RAS model domain and are parameterized simply by incorporating conceptual grading plans produced for each of the projects into the 2D area terrain data. Conceptual grading plans for each of the floodplain modification projects were developed consistently to lower the floodplain along one side of the channel to an elevation 2 to 3 feet above the adjacent channel invert over a reach length of 0.5 miles. The floodplain width was 200 feet at each location. As with detention basin concepts, factors such as property ownership, existing land uses, and topography were not considered in siting the projects. An example of the modeled floodplain modification concept is included as Figure 4 and cross sections for each of the tributaries are provided in Appendix B. Resulting hydrographs are included in Appendix A.

The Lynch Creek floodplain modification project was located within the XPStorm model domain and adjusting the natural channel section to reflect the same design described above.

## 1.3 Model Results

Model results were extracted at several model evaluation points distributed across the watershed as shown on Figure 5:

- Tributary extraction points were selected upstream and downstream from the five project concept sites shown in red on Figure 5. These collection points were used to gather data for consideration of the concepts' local impacts (within the tributary), which were not evaluated as part of this effort but will be considered during future evaluation of the concepts. A brief summary of the tributary level results is included in Section 3.1.2.
- Regional extraction points, shown in black on Figure 5, were selected to represent downstream reaches including the eastern tributaries (downstream from the confluence of Lichau and Willowbrook Creeks), western tributaries (downstream of the confluence of Liberty, Marin, Wiggins and Wilson Creeks), along the upstream reach of the Petaluma River, and along the downstream reach of the Petaluma River. While the regional sites are not directly impacted by projects in each of the modeled tributaries, combined, the four regional sites provide a ready comparison of the effects of the concept projects in the upper watershed as well as along the main stem of the river in the City of Petaluma.
- Overbank extraction points at known overbank flood locations, shown in blue on Figure 5, were identified in order to better evaluate flood benefits. Overbank flood duration data was extracted from the four unique off-channel locations, selected to represent areas that were significantly impacted by flooding during the December 31, 2005 storm event.

Simulated project concepts are representative of potential projects and the results were extracted with the primary purpose of providing quantified, relative estimates of flood management benefits for use in scoring and ranking the project concepts and tributary locations (discussed in the next section). Raw model results as well as the calculated changes from existing conditions for regional impacts are included in Appendix C. Raw model results as well as the calculated changes from existing conditions for local impacts are included in Appendix D.

Figure 1: Upper Petaluma River Tributary Sub-Watersheds for Concept Screening

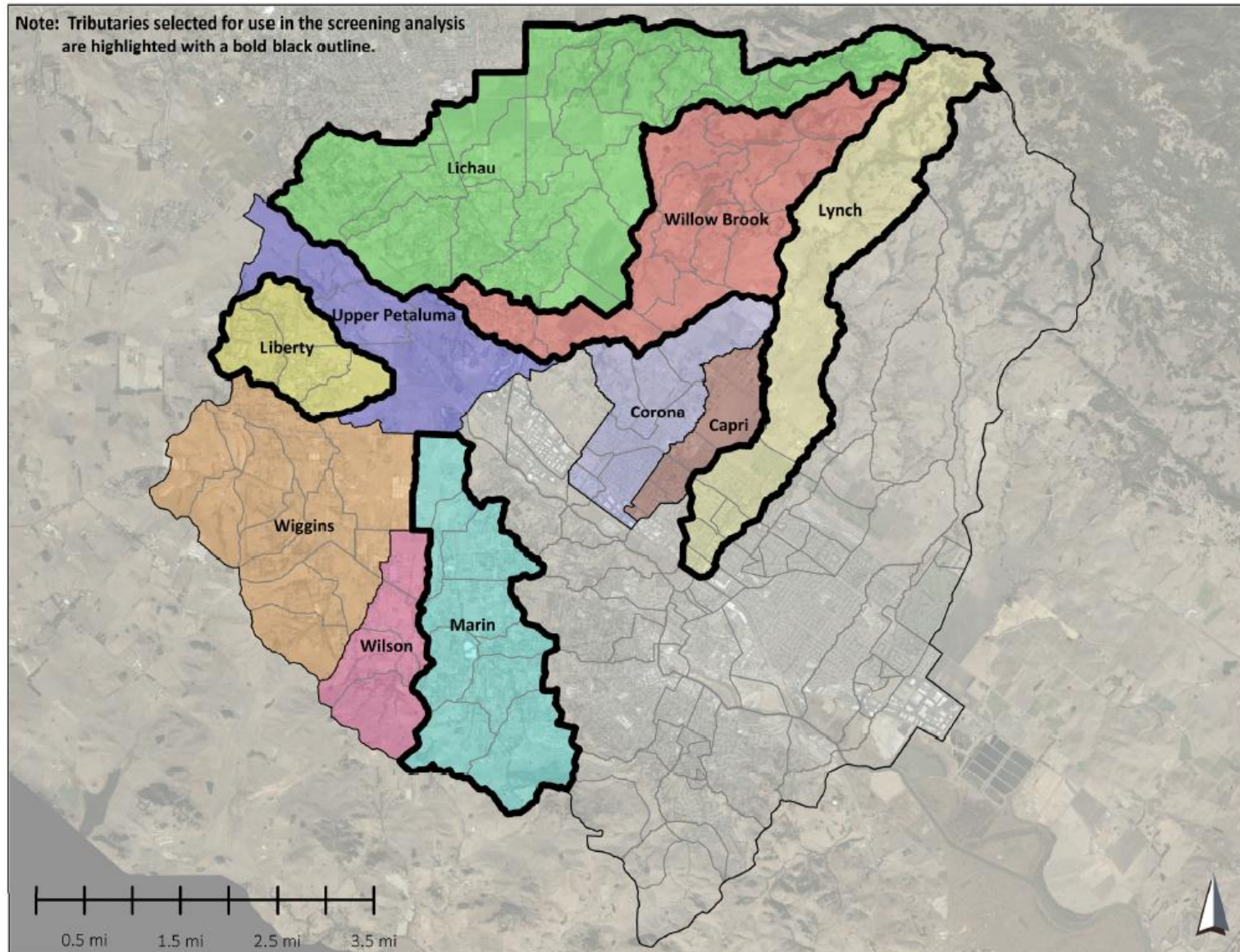
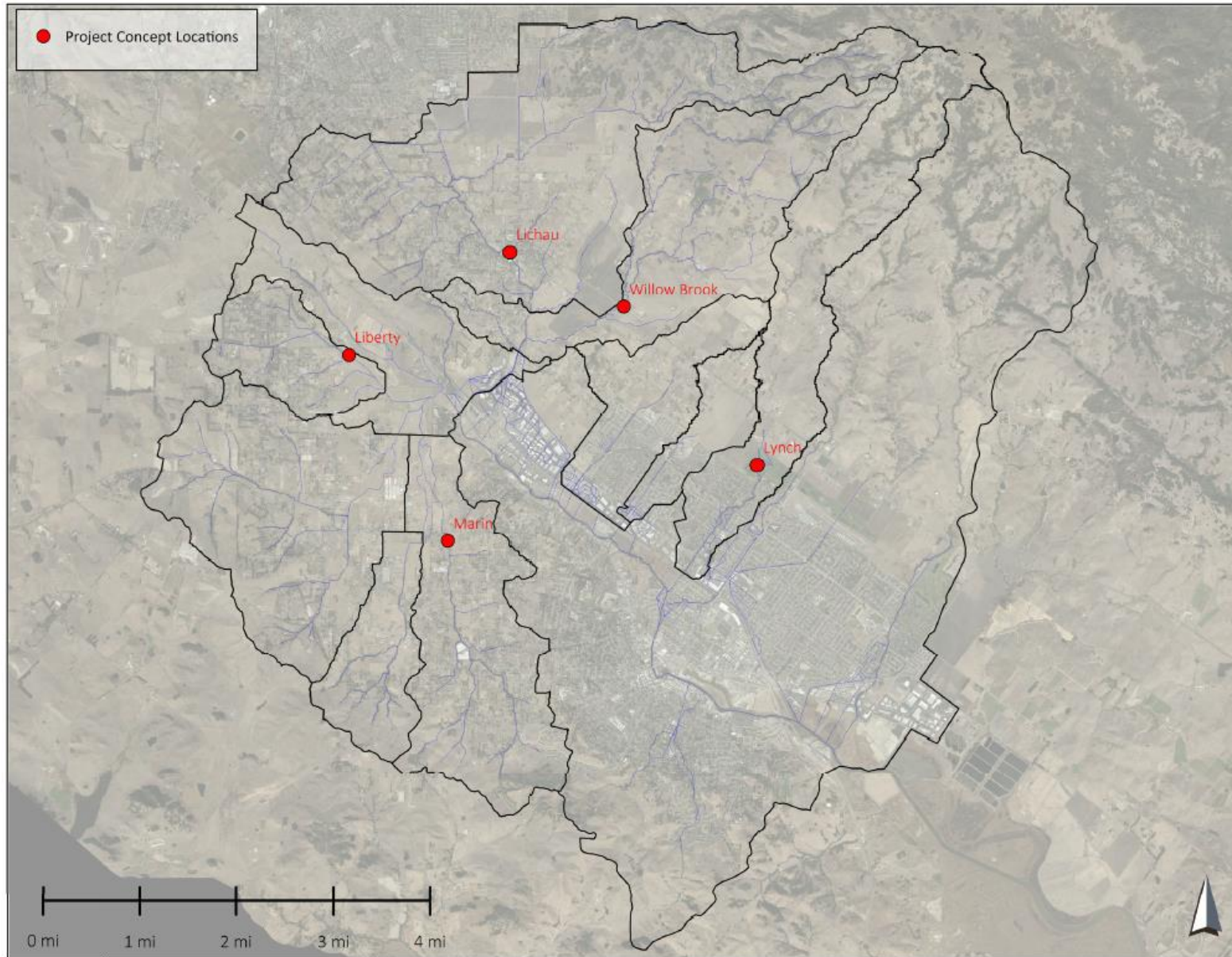
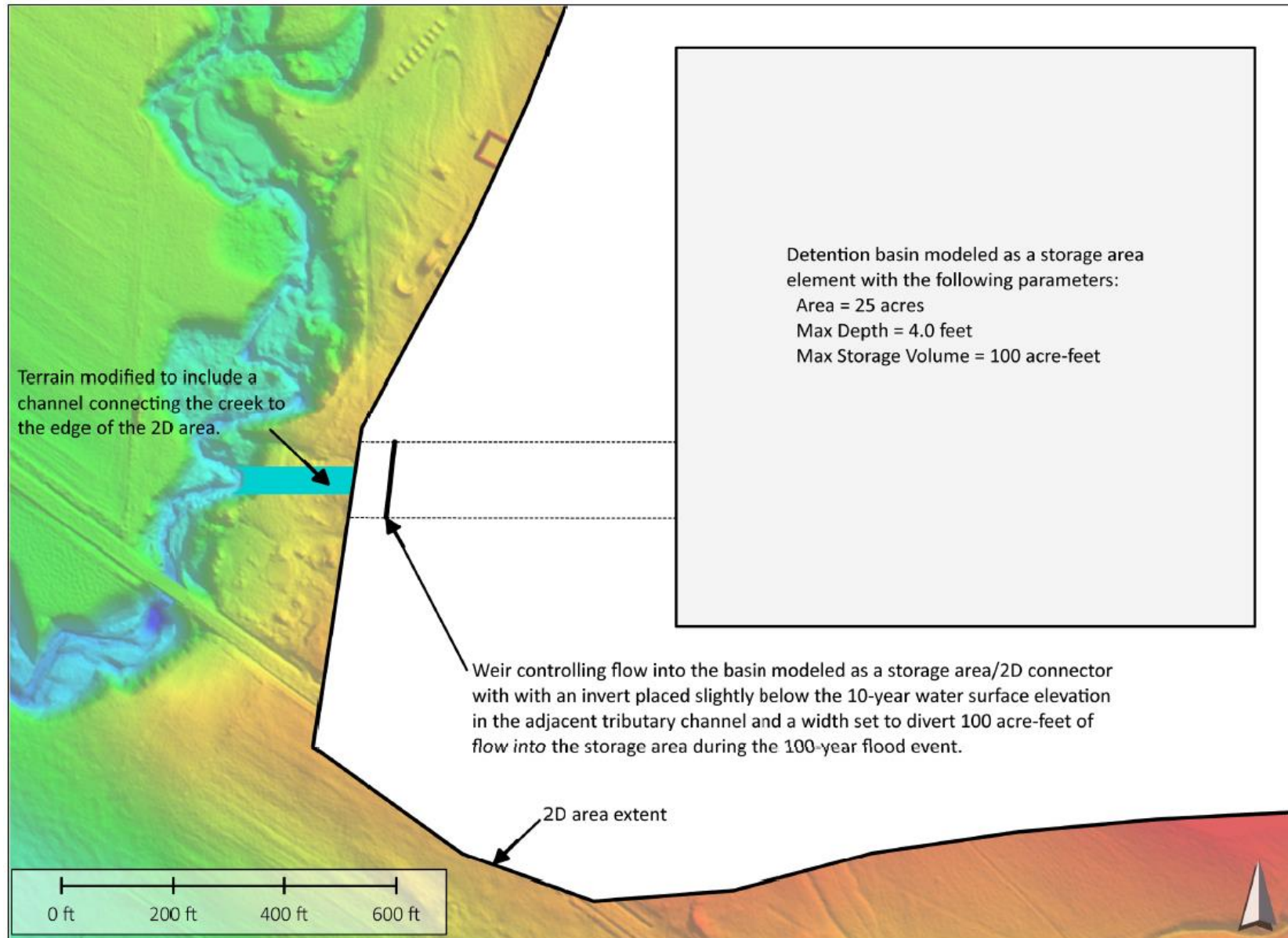




Figure 2: Project Concept Locations



**Figure 3: Example Detention Basin Concept**





**Figure 4: Example Floodplain Modification Concept**

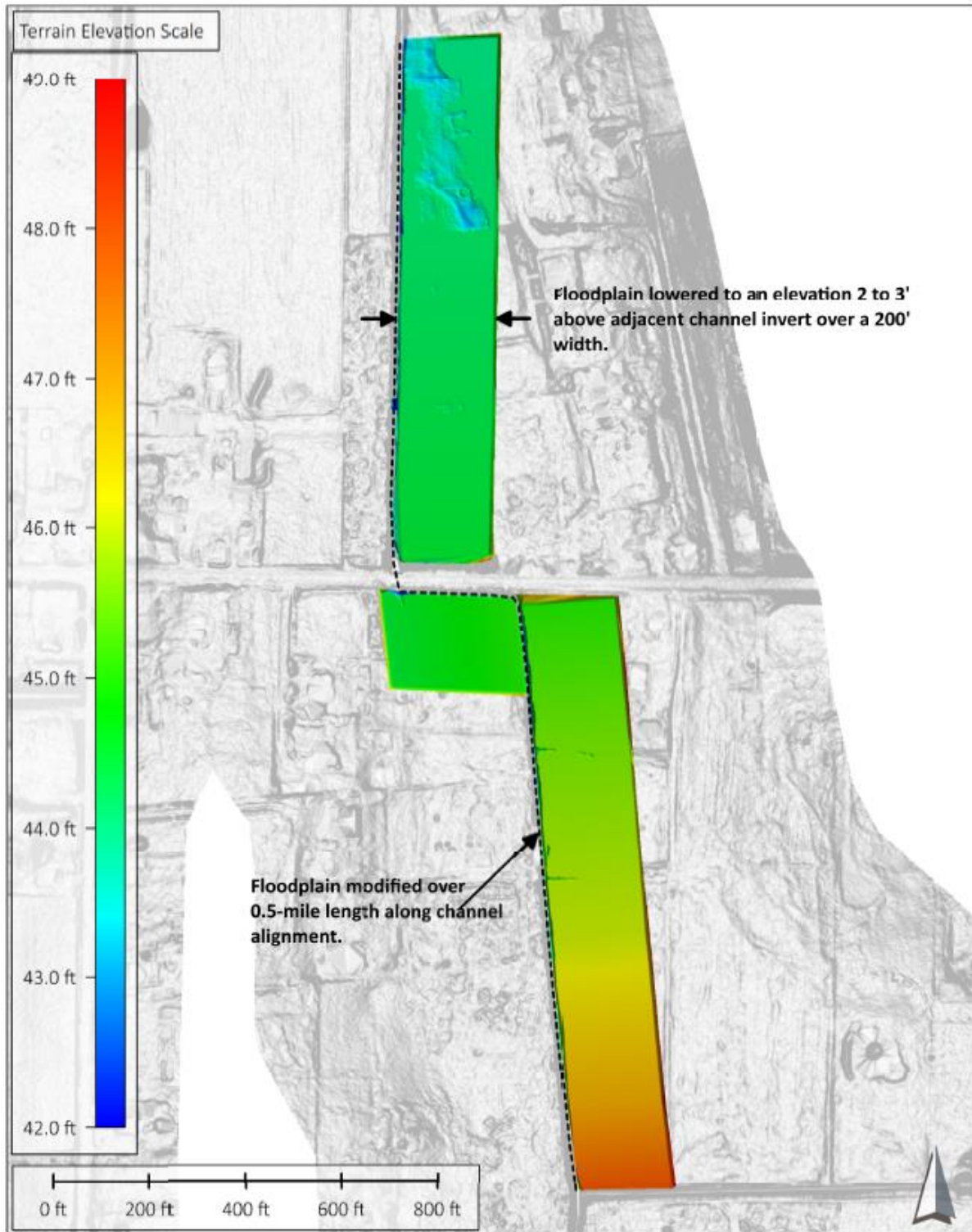
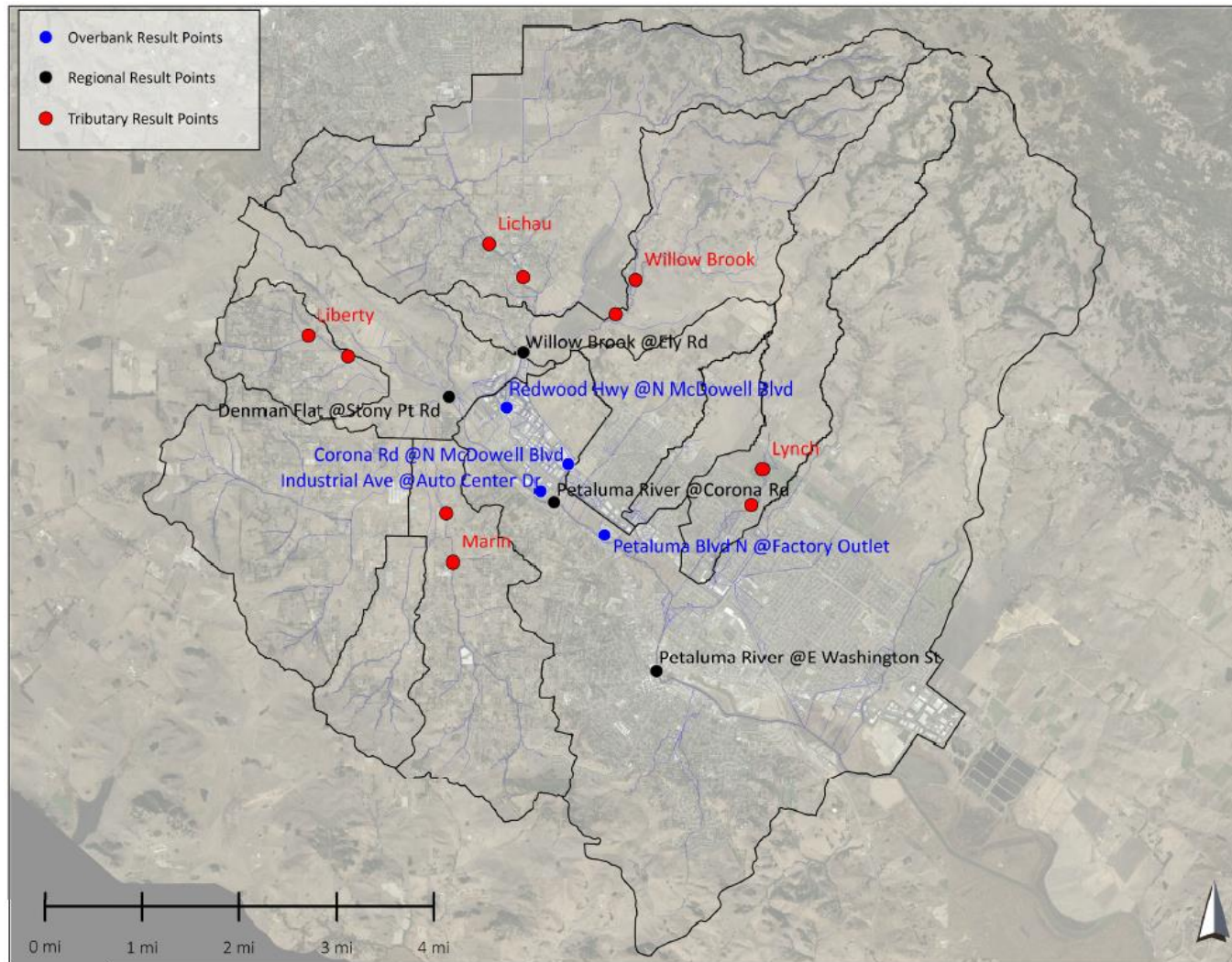


Figure 5: Flood Benefit Evaluation Points





## 2. CONCEPT SCORING, WEIGHTING AND RANKING

This section describes the establishment of criteria, scoring, weighting, and ranking for the concept alternatives. The purpose of this exercise is to identify potentially promising concepts and tributaries that provide the most flood benefit to carry forward to the next phase of the project when the project concepts will be further refined and advanced for further implementation consideration. This exercise focused on the regional impacts of each concept, however local impacts were documented for future consideration.

### 2.1 Criteria

A set of five criteria were used to score and rank the concepts for the initial screening. Of these criteria, four were measured at the same four junctions in the watershed (regional extraction points) and the fifth criteria (flood duration) was measured at four known flooding locations (overbank extraction points). A map of the data extraction points is included in Figure 5 and the criteria and extraction points are summarized in Table 1.

In addition to those evaluation points listed in Table 1 and shown in Figure 5, model results were also extracted immediately upstream and downstream of each of the concept implementation points (tributary extraction points). This data was not incorporated into the scoring/ranking process but was recorded for future consideration in the next phase of the project refinement and selection.

**Table 1: Concept Scoring Criteria and Model Extraction Location**

Criteria	Model Extraction Location
Flow rate <sup>1</sup>	<ol style="list-style-type: none"> <li>1. Willow Brook Creek at Ely Rd</li> <li>2. Denman Flat near Stony Pt Rd</li> <li>3. Petaluma River at Corona Rd</li> <li>4. Petaluma River at E Washington St</li> </ol>
Water surface elevation <sup>1</sup>	
Flood depth <sup>1</sup>	
Flood velocity <sup>1</sup>	
Flood duration <sup>2</sup>	<ol style="list-style-type: none"> <li>1. Redwood Hwy at N McDowell Blvd</li> <li>2. Industrial Ave at Auto Center Dr</li> <li>3. Corona Rd at N McDowell Blvd</li> <li>4. Petaluma Blvd N at Factory Outlet</li> </ol>

Notes:

1. Criteria was evaluated at the regional results points (black) shown in Figure 5.
2. Criteria was evaluated at overbank results points (blue) shown in Figure 5.

### 2.2 Raw Scoring

A simplified scoring system was applied to the modeled concepts, with three (3) being the highest possible score and one (1) being the lowest. Higher scores indicate that a concept provided more of a particular benefit. Scores were assigned for each criteria based on the results from the concept simulation, focusing on the regional results. Since each criteria has a different range of resulting model outputs, scores were set by breaking each range into three groups of scores. The highest scores were given to approximately 10-percent of concept/tributary combinations and the middle and low scores were applied roughly equally to the remaining concept/tributary model runs. This approach was taken for both the 10-year and 100-year storm events. A summary of the ranges of relative impacts for each criteria is presented in Table 2.

**Table 2: Concept Scoring Ranges**

Raw Score:	10-Year Storm			100-Year Storm		
	1	2	3	1	2	3
Change in Peak Flow Rate (cfs)	-5 <	-5 to -200	-200 >	-10 <	-10 to -370	-370 >
Change in Peak Water Surface Elevation (ft)	-0.005 <	-0.005 to -0.175	-0.175 >	-0.001 <	-0.001 to -0.25	-0.25 >
Change in Peak Flood Depth (ft)	-0.005 <	-0.005 to -0.175	-0.175 >	-0.005 <	-0.005 to -0.25	-0.25 >
Change in Peak Velocity (fps)	-0.005 <	-0.005 to -0.175	-0.175 >	-0.005 <	-0.005 to -0.1	-0.1 >
Change in Overbank Flood Duration (hr)	0 <	0 to -0.1	-0.1 >	-0.005 <	-0.005 to -0.196	-0.196 >

### 2.3 Weighting and Final Score

Concept criteria were weighted against each other based on input from Sonoma Water and the implication of the criteria on the potential reduction in flooding and related damage. Criteria more closely associated with the presence of flooding (flow rate and flood duration) were weighted higher. A summary of criteria weighting is presented in Table 3.

**Table 3: Concept Scoring Criteria Weighting**

Criteria	Criteria Weight <sup>1</sup>
Flow rate	2
Water surface elevation <sup>2</sup>	1
Flood depth <sup>2</sup>	1
Flood velocity	1
Flood duration	2

Notes:

1. Criteria was weighted the same for 10-year and 100-year events.
2. Water surface elevation and flood depth represent similar impacts and thus were weighted lower so as not to over-emphasize those criteria.

These criteria weights were multiplied by the previously assigned scores to produce a weighted score for each criteria, shown below:

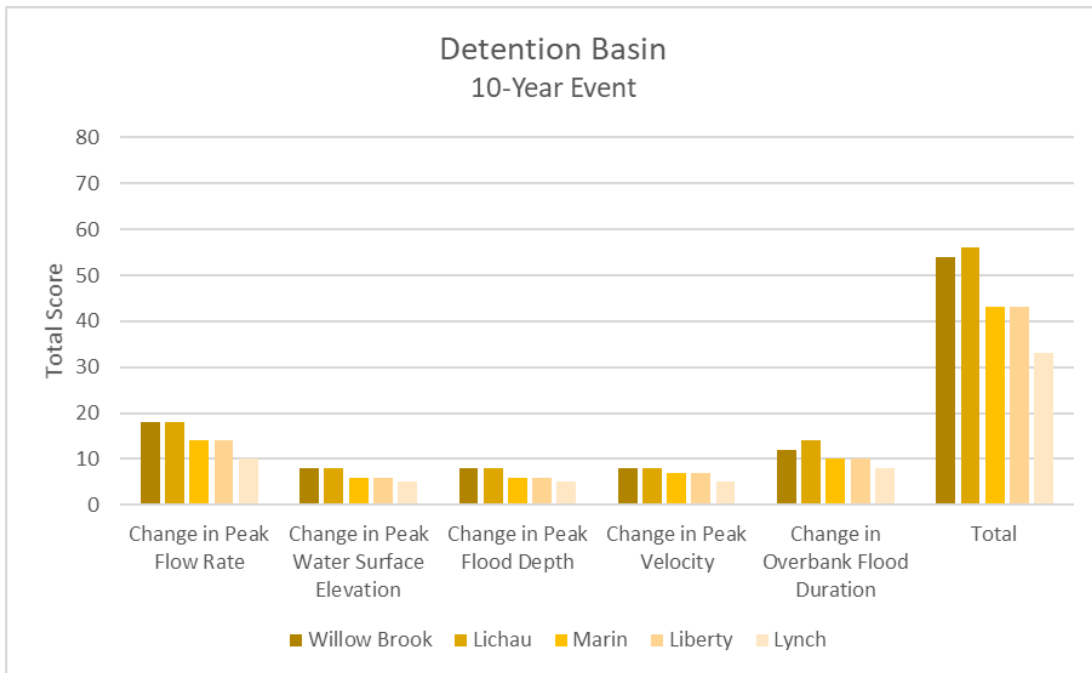
$$\text{Weighted Criteria Score} = \text{Raw Criteria Score} * \text{Criteria Weight}$$

The weighted scores were calculated for each criteria at each model extraction point and then summed together to determine the total weighted criteria score. The calculation (for all but the flood duration criteria) is shown below:

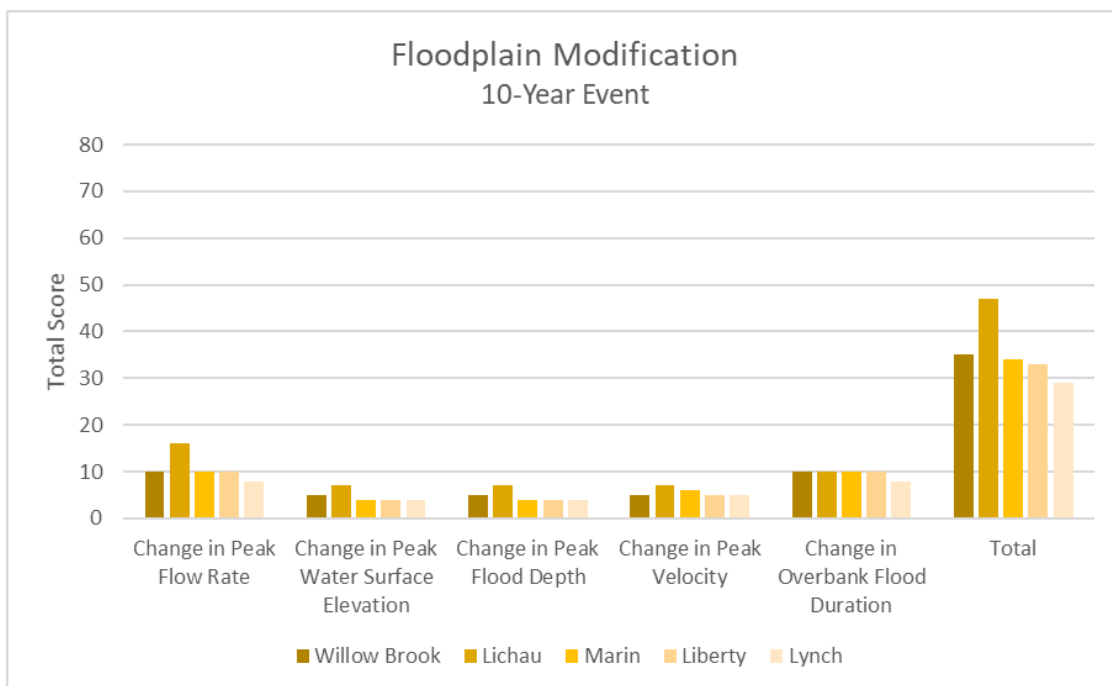
$$\begin{aligned} \text{Total Weighted Criteria Score} = & [\text{Weighted Criteria Score @Willow Brook Creek at Ely Rd}] \\ & + [\text{Weighted Criteria Score @Denman Flat at Stony Pt Rd}] \\ & + [\text{Weighted Criteria Score @Petaluma River at Corona Rd}] \\ & + [\text{Weighted Criteria Score @Petaluma River at E Washington St}] \end{aligned}$$

The total weighted scores were then summed to determine the final concept alternative score. An overview of the total weighted and final scores are presented in Figure 6 through Figure 9. The final weighted and total scores are presented in Appendix E.

**Figure 6: 10-Year, Detention Basin Total Concept Weighted Criteria and Total Scores**

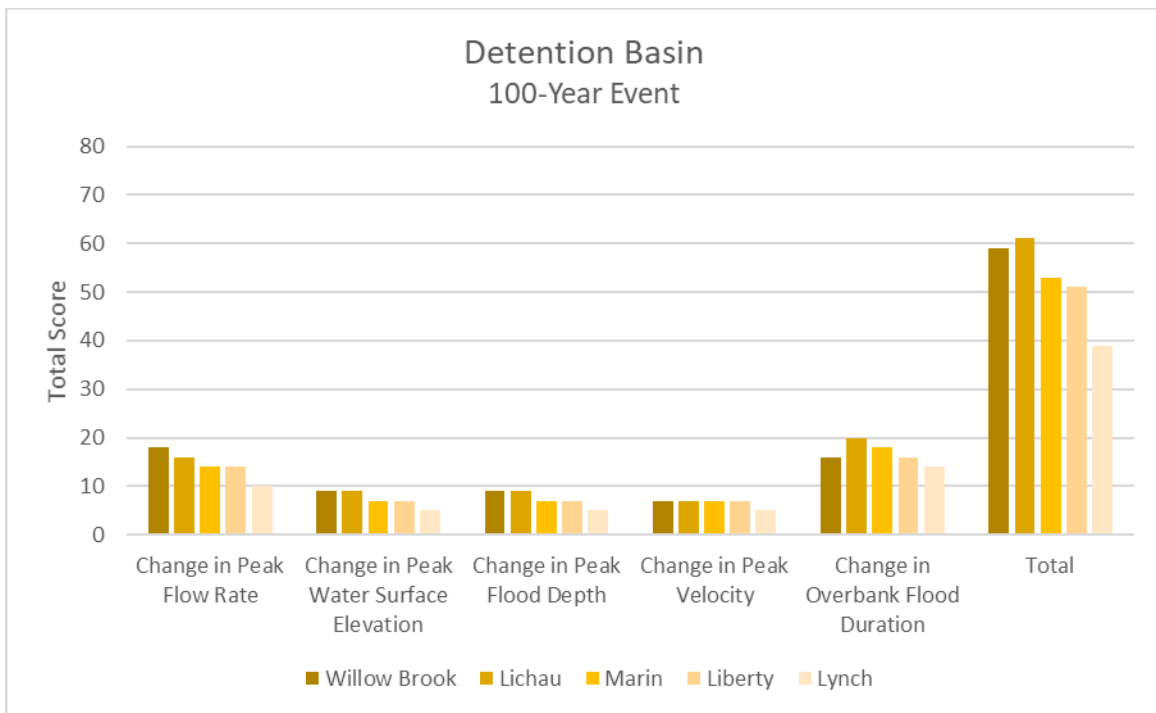


**Figure 7: 10-Year, Floodplain Modification Total Concept Weighted Criteria and Total Scores**

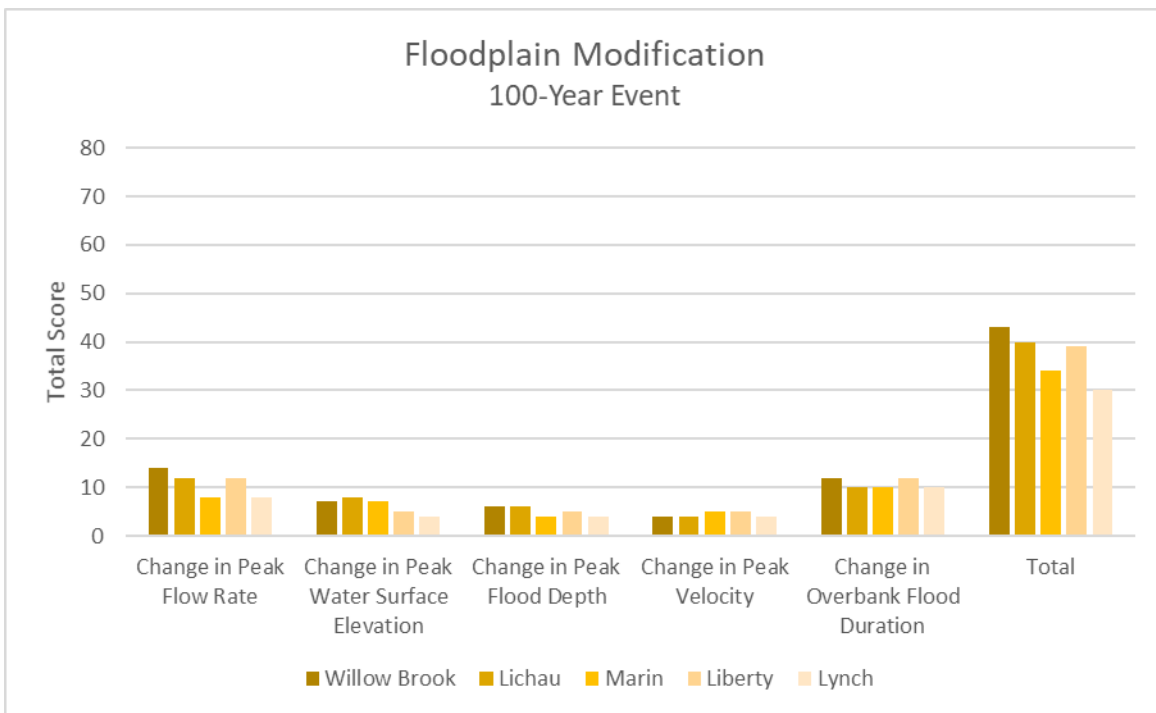




**Figure 8: 100-Year, Detention Basin Total Concept Weighted Criteria and Total Scores**



**Figure 9: 100-Year, Floodplain Modification Total Concept Weighted Criteria and Total Scores**



## 2.4 Concept Ranking

Based on the final score presented in the previous section, the concept alternatives were ranked for the 10-year, 100-year and overall scores. A summary of the concept ranking is presented in Table 4. A discussion of these rankings is presented in the following sections.

**Table 4: Concept Ranking**

Design Event		Detention Basin Scenario					Floodplain Modification Scenario				
		Willow Brook	Lichau	Marin	Liberty	Lynch	Willow Brook	Lichau	Marin	Liberty	Lynch
10-Year	Score	54	56	43	43	33	35	47	34	33	29
	Rank	2	1	4	4	8	6	3	7	8	10
100-Year	Score	59	61	53	51	39	43	40	34	39	30
	Rank	2	1	3	4	7	5	6	9	7	10
Overall	Score	113	117	96	94	72	78	87	68	72	59
	Rank	2	1	3	4	7	6	5	9	7	10

### 2.4.1 Concept Ranking by Location

The concept rankings were also broken down specifically by the impacts at a given model evaluation point. Based on the model results, detention basin projects have a greater potential to provide regional benefits. Larger tributaries (Willow Brook or Lichau), and/or those situated immediately adjacent to the modeled evaluation points (varies based on the evaluation point), were also more likely to have a higher impact on regional flood reduction. A summary of the top ranked concept(s) at each location are presented in Table 5 and a detailed breakdown is included in Appendix E.

**Table 5: Top Concepts by Model Evaluation Point**

Model Evaluation Point	Top Ranked Concept	Criteria Considered
Willow Brook Creek at Ely Rd	Detention Basin (Willow Brook or Lichau)	Peak Flow Peak Water Surface Elevation Peak Flood Depth Peak Velocity
Denman Flat near Stony Pt Rd	Detention Basin (Marin or Liberty)	
Petaluma River at Corona Rd	Detention Basin (Willow Brook, Lichau, Marin or Liberty)	
Petaluma River at E Washington St	Detention Basin (Willow Brook)	
Redwood Hwy at N McDowell Blvd	Detention Basin (Lichau)	Flood Duration
Industrial Ave at Auto Center Dr	Detention Basin (Lichau, Marin or Liberty) or Floodplain Modification (Willow Brook or Liberty)	
Corona Rd at N McDowell Blvd	Detention Basin (Lichau)	
Petaluma Blvd N at Factory Outlet	Detention Basin (Willow Brook, Lichau or Marin)	

### 2.4.2 Concept Ranking Sensitivity

A sensitivity analysis was conducted to determine the impact of changes to the criteria weighting on the concept ranking. The analysis included equal weighting as well as emphasizing individual criteria. Results of that assessment show that adjustments to criteria weights did not produce significant changes in the rankings. The top six concepts remained the same regardless of weighting. Rank changes were only noted among the bottom four concepts.

### 3. CONCLUSIONS AND KEY TAKEAWAYS

In addition to the scoring and ranking process detailed in the previous section, the raw model results (visual, non-quantitative output from the model) were reviewed and considered as part of the assessment of the project concepts. Based on review of the raw model outputs as well as the results of the scoring/ranking process, the concept screening analysis supports several key takeaways:

- The flood reduction benefits resulting from the detention projects are more significant than those resulting from the floodplain modification projects.
- Offline detention is less likely to result in adverse downstream flood impacts compared with online detention (represented by the floodplain modification projects) as offline detention (with a controlled release of flow back into the creek) allows for flow to be held and not reenter the creeks along the tail end of the hydrograph. It is important to note that the detention basins modeled as part of this effort are simplified and do not include all components of a real detention basin.
- Floodplain modification projects provide a greater peak flow attenuation benefit in locations with an existing downstream constriction such as a culvert under an elevated roadway.
- Peak flow attenuation benefits are more significant from projects along the Willow Brook and Lichau Creek tributaries due to their larger size and sharply peaked hydrographs.
- Peak flow attenuation benefits are less significant from projects along the Marin and Liberty Creek tributaries compared to other tributaries due to the significant attenuation already provided through Denman Flats. As suggested by the Army Corps of Engineers and City of Petaluma, the “natural” detention provided by the Denman Flats could be complimented by a specifically tailored project to provide enhanced flood reduction benefits.
- Peak flow attenuation benefits are less significant from projects along Lynch Creek given the inability of the projects to impact upstream reaches, the existing attenuation provided along the golf course, and the timing of peak flows along Lynch Creek and the Petaluma River not coinciding.

#### 3.1 Limitations of the Concept Screening Analysis

The screening presented in this TM is intended to serve as a steppingstone to the next phase of the Upper Petaluma Flood Control Project Feasibility study when projects will be refined and further evaluated for feasibility. Heading into the next phase, it is important to keep in mind the limitations and assumptions of the concept screening presented in this TM. This evaluation focused on ranking project concept/location combinations based on regional impacts while local benefits were recorded (Appendix D) for future consideration. Project priorities—such as the selection of a design event or emphasizing regional or local benefits—will need to be finalized. Once those priorities are determined, further evaluation can be conducted to determine more specific project alternative details. For example, the project locations selected for the concept screening in this evaluation do not necessarily represent viable project sites. More work will be needed to identify feasible locations for projects to be constructed that will provide both the expected flood reduction benefits while also achieving other project goals identified during the biological impact study, cultural resource review, and public outreach. Additionally, storage areas modeled may increase or decrease based on site conditions once project locations are refined.

##### 3.1.1 Prioritization of 10- or 100- Year Event

As discussed in Section 1, the models were set up so that each of the concepts would provide flood control benefits for both the 10- and 100-year event. That said, the concepts were not optimized for either storm event. While this approach provided a valuable overview of the potential impacts of the project concepts, an emphasis on either 10- or



100- year results would better demonstrate the actual impact of the project concept. It is recommended that the 10- year event serve as the primary design event during the next phase of the concept development to further develop and optimize project alternatives for reducing more frequent flooding impacts. Use of the 10-year event will provide more obvious and consistent benefits to project stakeholders. However, it should be noted that the 100-year event analysis should still be carried forward in order to be presented as part of applications for Hazard Mitigation Grant Program funding through FEMA.

### 3.1.2 Regional versus Local Benefits

The concept scoring, weighting and ranking focused on the regional impacts of the project concept as those model evaluation points allowed for more direct comparison between the concept/tributary combinations. The local project benefits were recorded (Appendix D) but not incorporated into the scoring.

The exclusion of local results from the scoring, weighting and ranking means that concepts that may have significant local (in-tributary) impacts were scored and ranked lower than those concepts whose impacts were felt across a greater portion of the watershed. Projects that can provide local, but not regional, benefits should not be removed from consideration. Those projects may be best utilized as a secondary project to support a larger effort or a specialized project to address a significant local issue. For example, a project along Lynch Creek would have a low regional impact but would address flooding concerns at East Washington Street. The top-ranking projects for each model evaluation point (presented in Table 5) along with the local results in Appendix D are a starting point should a locally-driven project be considered.

#### 3.1.2.1 Local Benefits Overview

A brief overview of the tributary level results is included below, and summarized in Table 6, to highlight potential local project benefits and general findings for consideration during the next phase of concept development. At the tributary level, model results are more sensitive to the details and siting of the concept designs as well as the placement of the results extraction points. As a result, the following conclusions are provided at a high level with the understanding that localized flood benefits should be assessed in the context of unique objectives defined at each project location and with project concepts refined to meet those objectives:

- Peak flow attenuation benefits resulting from the detention projects are more significant than those resulting from the floodplain modification projects.
- Floodplain modification projects generally result in lower water surface elevations upstream from the project sites than the detention projects, while the detention projects generally result in lower water surface elevations downstream from the project sites.
- Lowered water surface elevations often result in increased channel velocities.

Model outputs corresponding to this summary of local impacts are included in Appendix A (hydrographs from downstream of the project site in the tributary) and Appendix D (numerical outputs).

**Table 6: Project Concept with Greatest Likely Impact at Tributary Level**

Criteria	Upstream of Project	Downstream of Project
Peak Flow Rate	<i>n/a</i>	Detention Basin
Peak Water Surface Elevation	Floodplain Modification	Detention Basin
Peak Flood Depth	Floodplain Modification	Detention Basin
Peak Velocity	Floodplain Modification	Detention Basin

### 3.1.3 Application to Unmodeled Tributaries

It is important to keep in mind that the screening analysis was limited to a representative selection of five tributaries. The results of the analysis presented in this TM can be projected to the un-modeled tributaries based on the hydrologic characteristics (presented in the Tributary Selection Basis TM). For those concepts that rank highly and may be considered for further evaluation, similar concepts could be considered in the associated unmodeled tributaries. An approximation of how results from modeled tributaries can be applied to unmodeled tributaries is presented in Table 7 with a comparison of key watershed characteristics summarized in the Tributary Selection TM.

**Table 7: Application of Model Results to Un-Modeled Tributaries**

<b>Results from (modeled tributary):</b>	<b>May be applied to (unmodeled tributary):<sup>1</sup></b>
Willow Brook	None
Lichau	None
Marin	Wiggins and Wilson
Liberty	Upper Petaluma, Corona and Capri
Lynch	Corona and Capri

Notes:

1. Additional details regarding the selection of the model tributaries and how they represent the unmodeled tributaries can be found in the Tributary Selection TM (May 2019).

## 4. NEXT STEPS

This memo summarizes modeling completed with the purpose of producing quantified estimates of flood control benefits across a range of project scenarios for use in scoring and ranking the project concepts and tributaries. The next phase of this project will more completely develop project concepts site and selection with the goal of developing conceptual designs for potential projects. This effort may include:

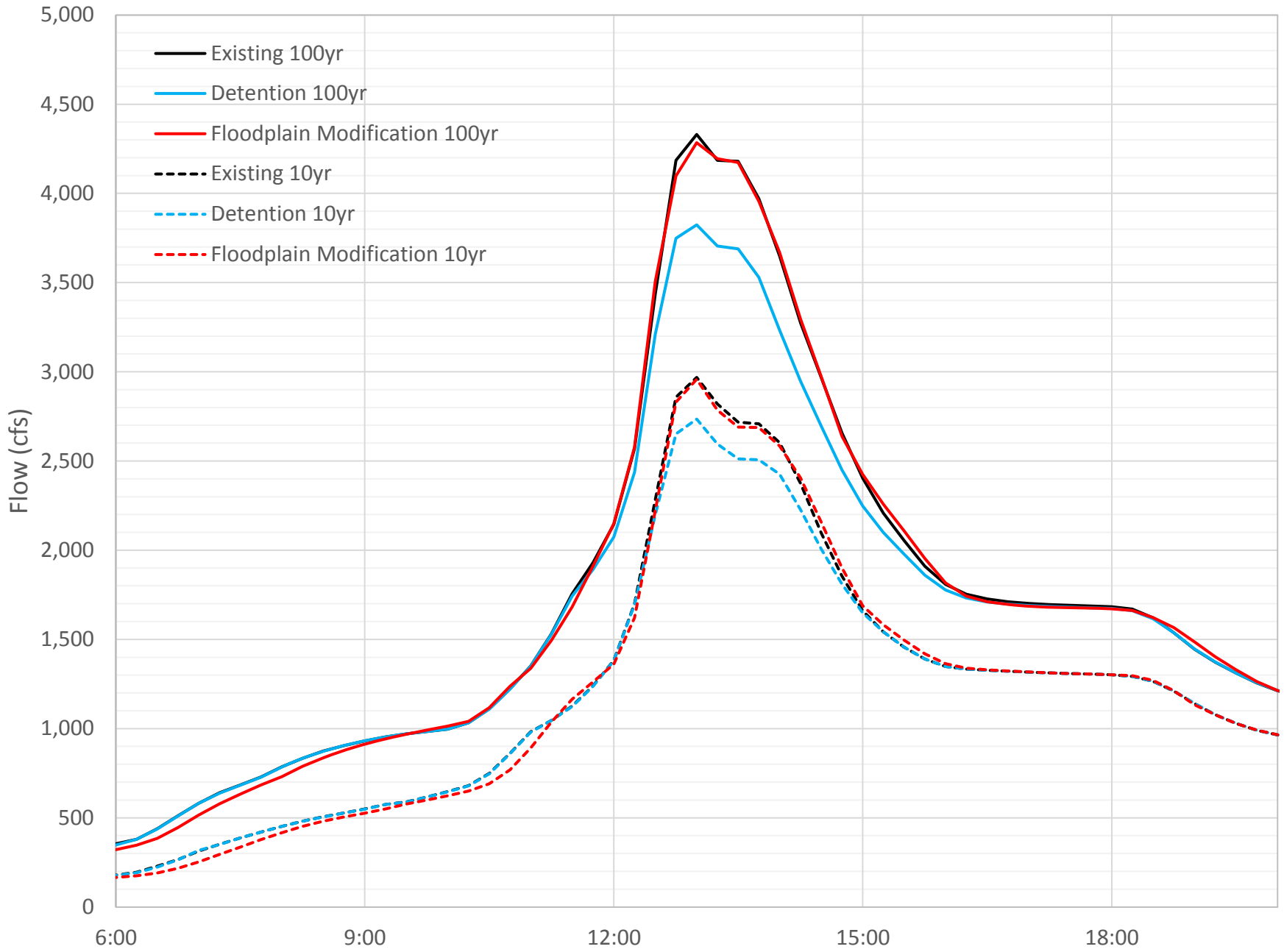
- Assessment of other project types (restoration, recharge, etc.)
- Confirm selection of a design storm event
- Refinement of project location within the tributary to optimize project impacts
- Refinement of concept sizing based on likely or possible properties

Additionally, further coordination is expected with other stakeholders in the watershed to ensure a comprehensive plan to address flood management throughout the Petaluma watershed. This will include gathering stakeholder and public feedback through the Zone 2A committee as well as coordination between modeling efforts throughout the watershed to ensure consistency between models. Stakeholder coordination will also be critical for determining project funding opportunities. Two complimentary studies are underway to inform siting, further develop project concept feasibility and engage stakeholders. These two efforts include: 1) update of the Petaluma Watershed Enhancement Plan, prepared by the Sonoma Resource Conservation District and Friends of Petaluma River, with broad stakeholder participation including Sonoma Water and City of Petaluma, and 2) Stormwater Management Suitability Analysis, conducted by UC Berkeley for Sonoma Water. This suitability analysis will allow important non-technical factors to be considered in tandem with traditional hydrologic and engineering feasibility performed as part of this first step in Feasibility Study.

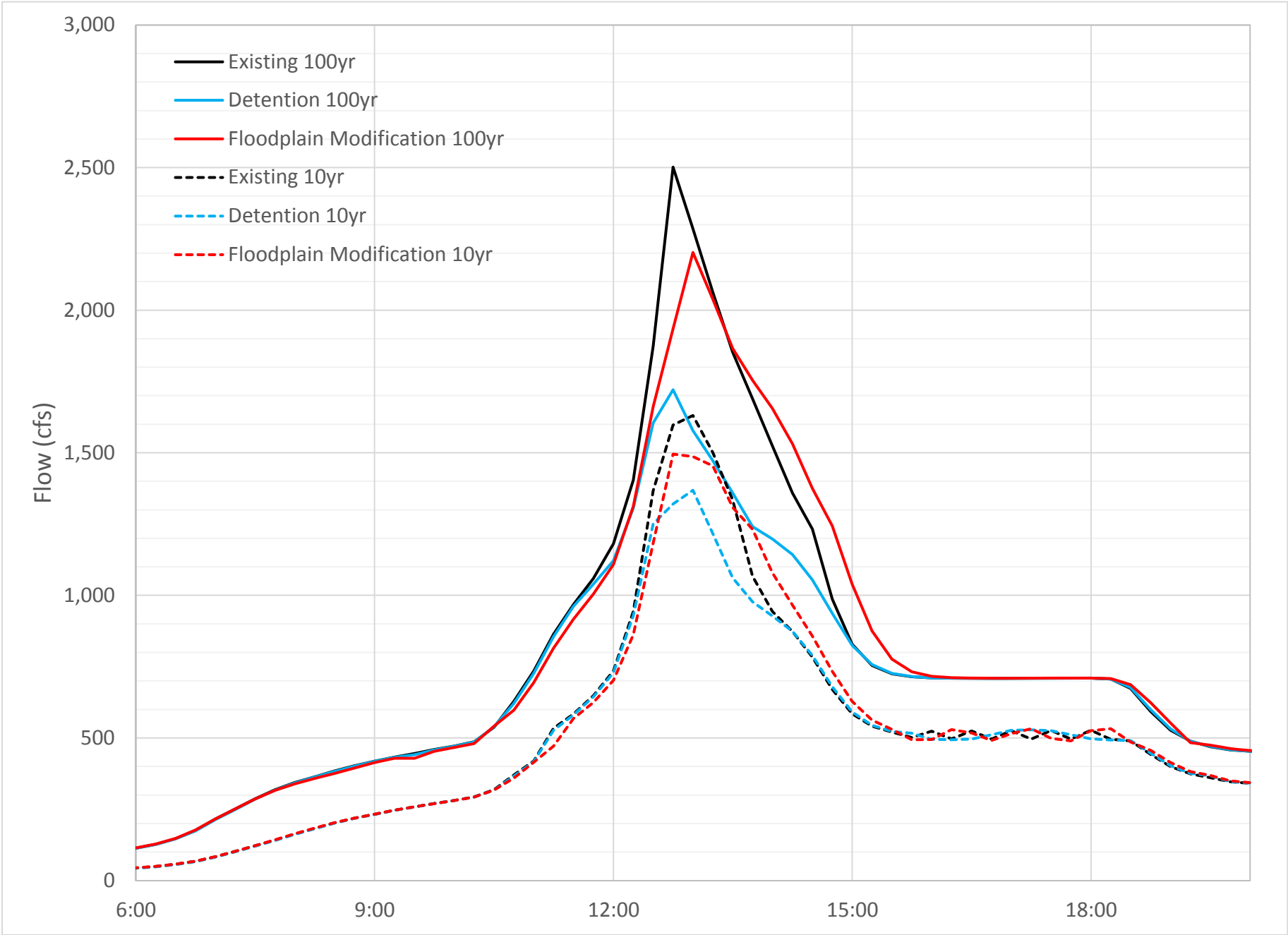
Implementation of flood management projects should be planned in accordance with watershed wide planning efforts. Concept designs should consider provision of multiple benefit types in concert with flood management, such as benefits to water quality, habitat, recreation and public access/engagement, where feasible. Sonoma Water will identify the necessary coordination efforts for consideration during the next phase of the project.



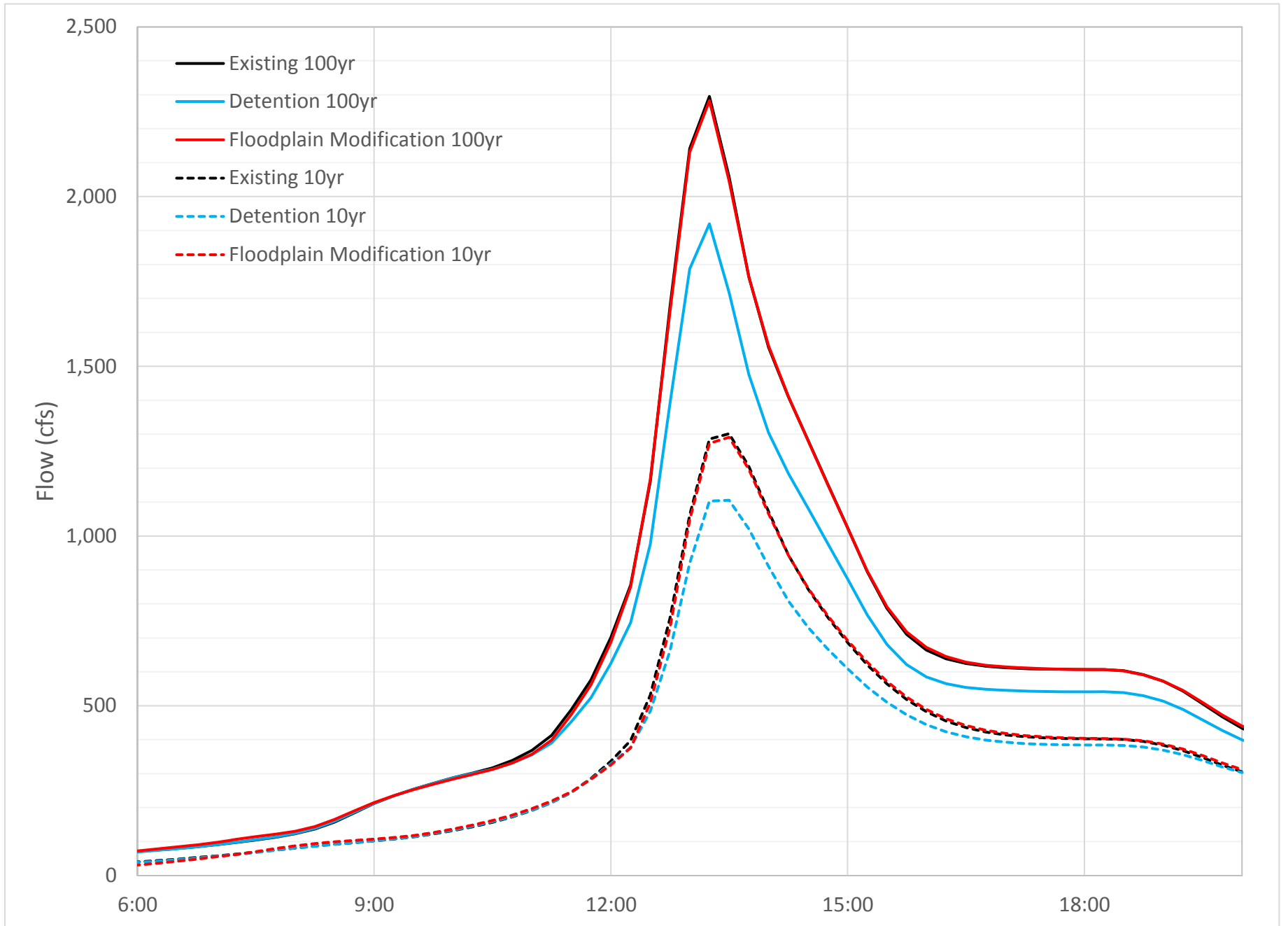
**APPENDIX A: PROJECT CONCEPT MODEL RESULTS – LOCAL  
HYDROGRAPHS**



Lichau Creek hydrograph comparison

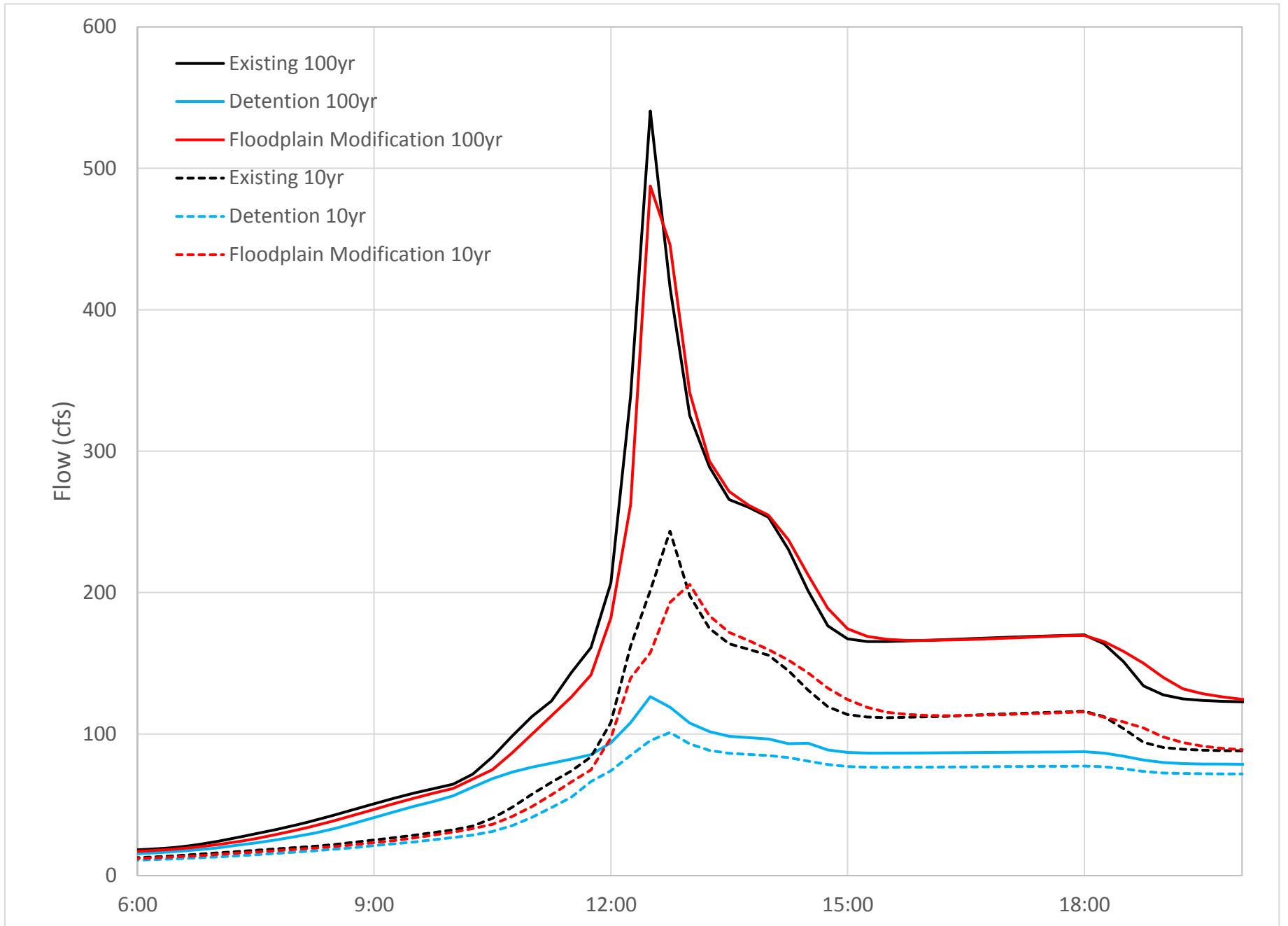


Willow Brook Creek hydrograph comparison

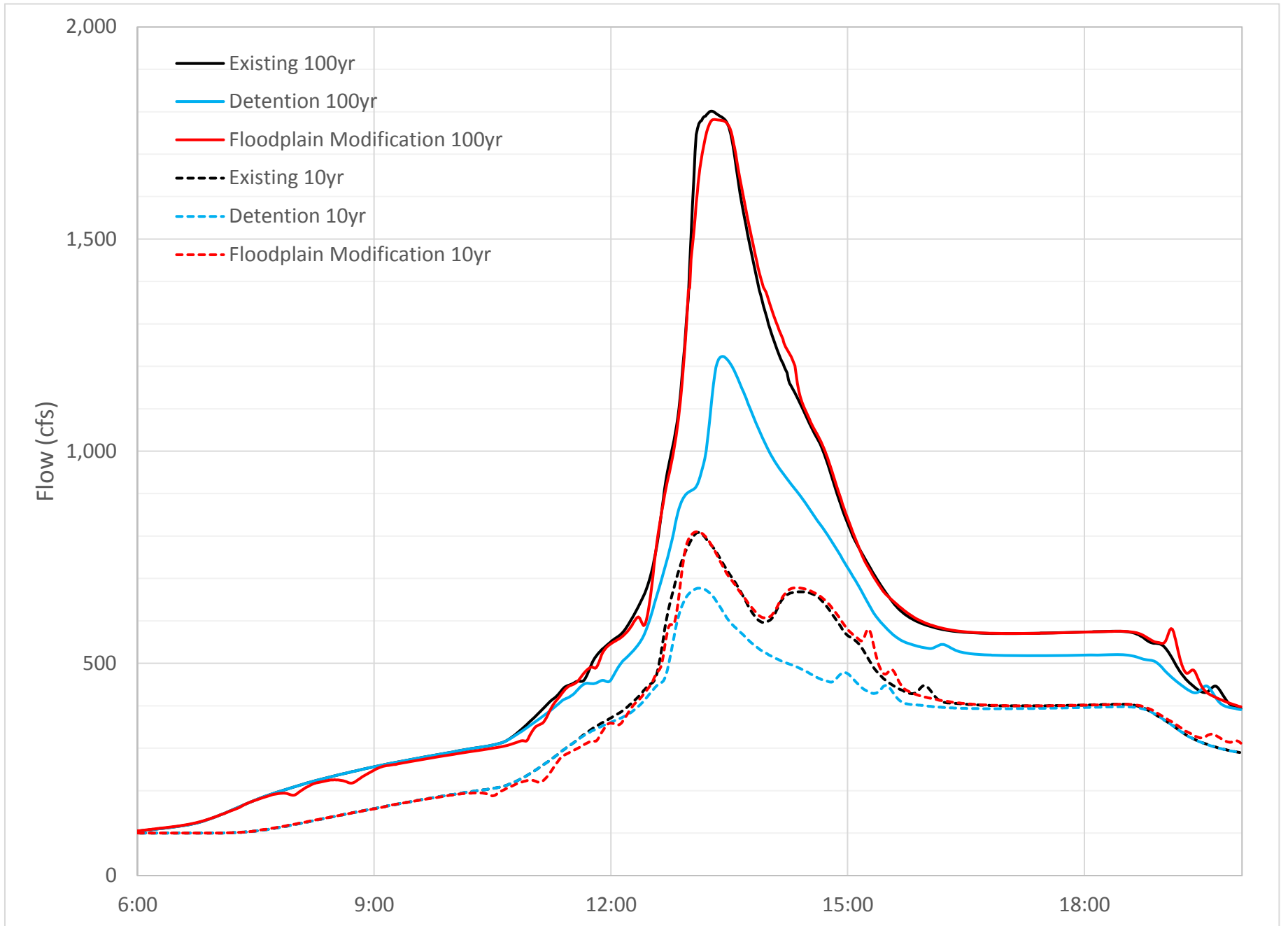


Marin Creek hydrograph comparison



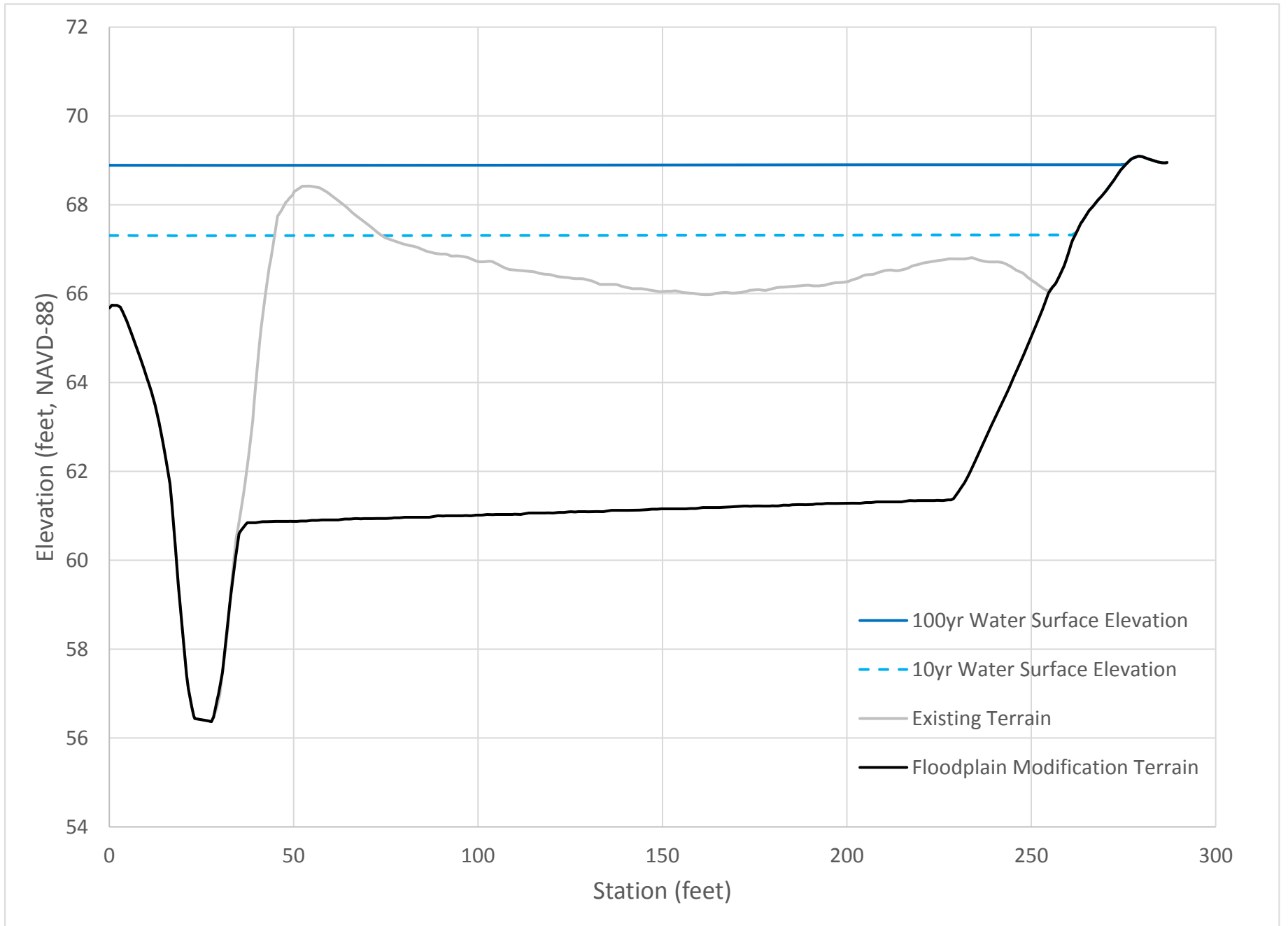


Liberty Creek hydrograph comparison



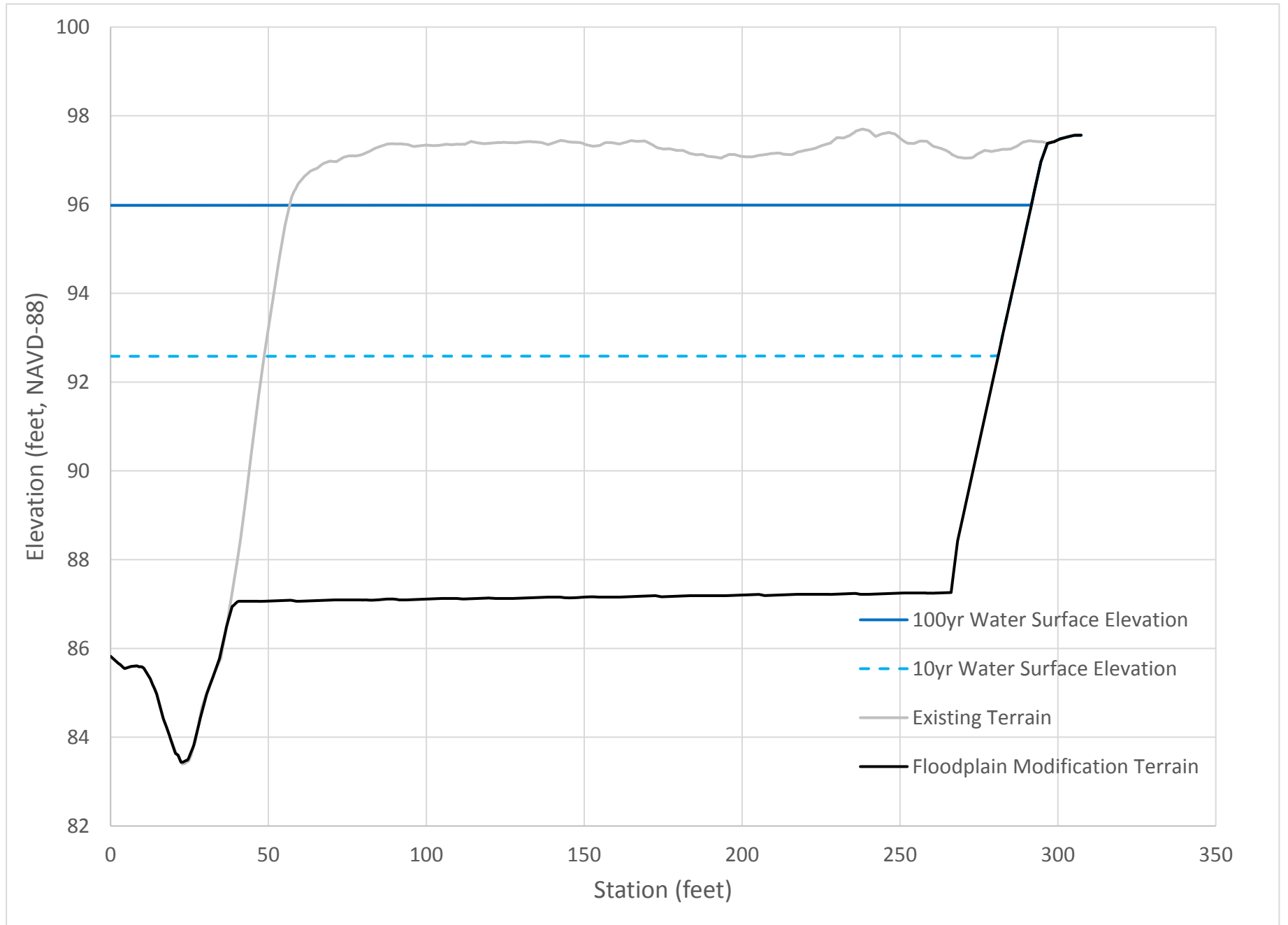
Lynch Creek hydrograph comparison

## **APPENDIX B: FLOODPLAIN MODIFICATION CROSS SECTIONS**

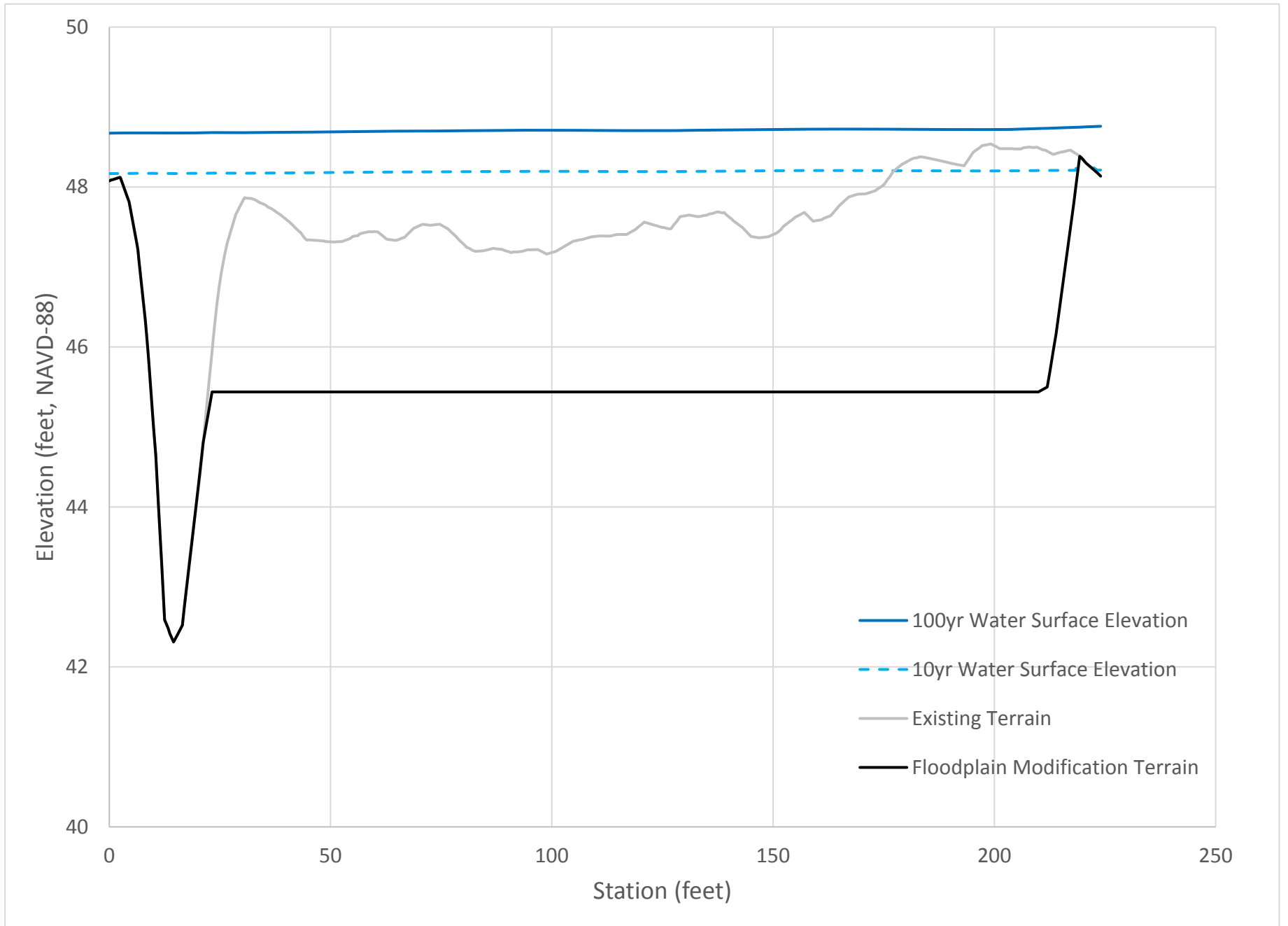


Lichau Creek representative floodplain section.

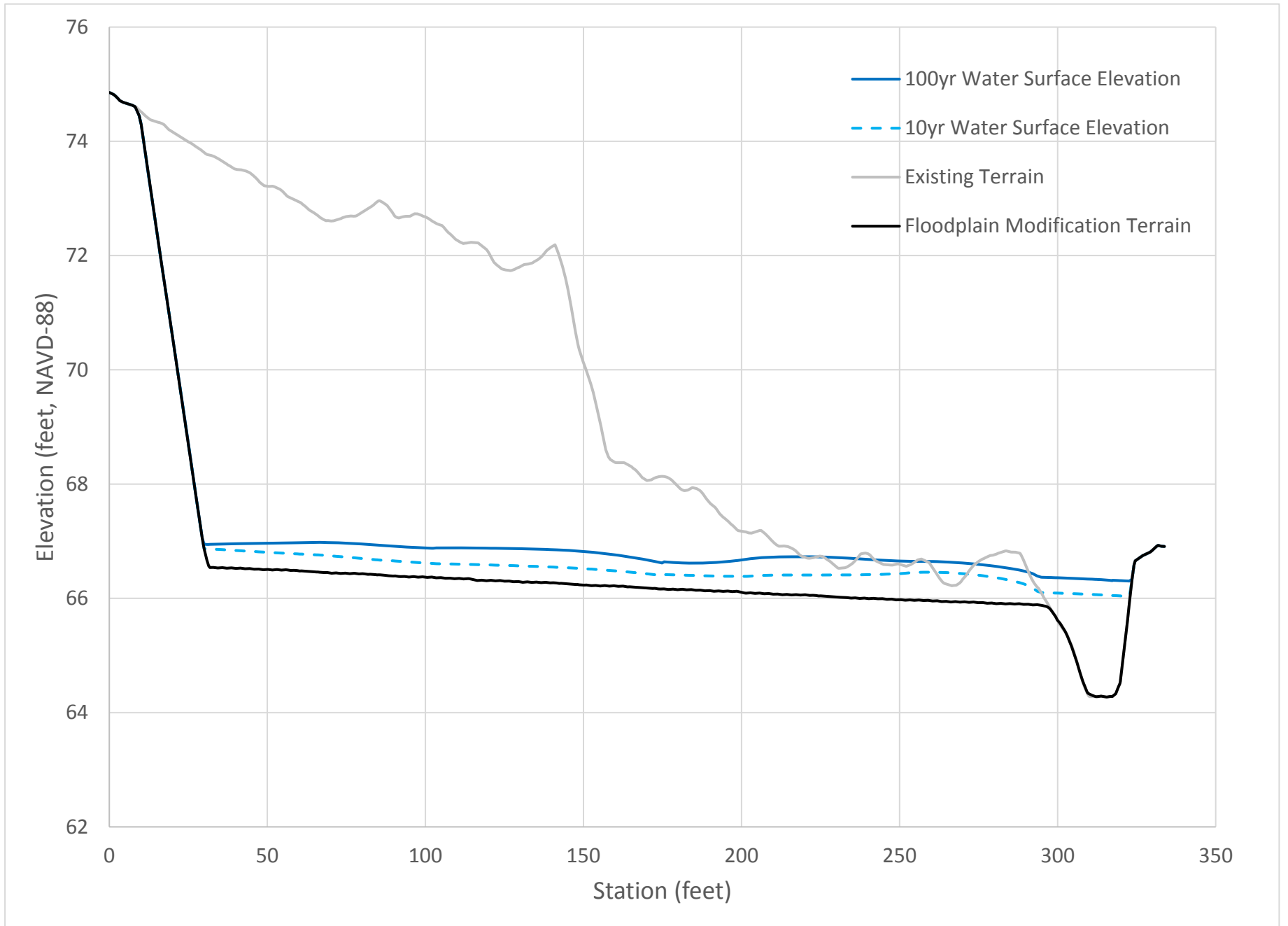




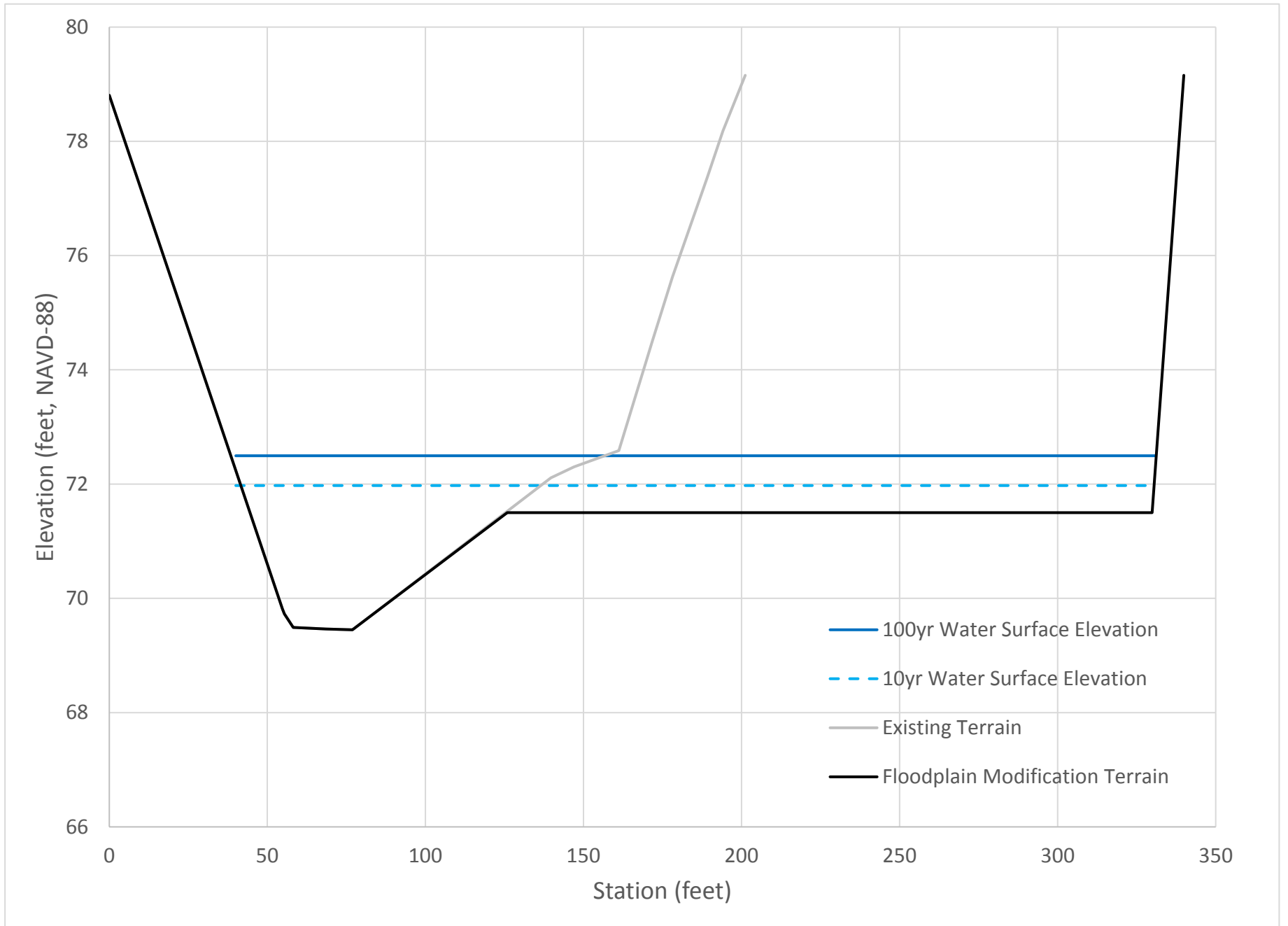
Willow Brook Creek representative floodplain section.



Marin Creek representative floodplain section.



Liberty Creek representative floodplain section.



Lynch Creek representative floodplain section.



## **APPENDIX C: MODEL RESULTS – REGIONAL IMPACTS**

## 10-Year Model Results – Raw Model Output

### Scenario Model Output: 10-year Flood

Model Evaluation Point	Peak Flow Rate										
	Detention Basin Scenario					Floodplain Modification Scenario					
	Existing	Willow Brook	Lichau	Marin	Liberty	Lynch	Willow Brook	Lichau	Marin	Liberty	Lynch
	<i>cfs</i>	<i>cfs</i>	<i>cfs</i>	<i>cfs</i>	<i>cfs</i>	<i>cfs</i>	<i>cfs</i>	<i>cfs</i>	<i>cfs</i>	<i>cfs</i>	<i>cfs</i>
Willow Brook Creek at Ely Rd	5,424	5,173	5,211	5,424	5,424	5,424	5,269	5,400	5,424	5,424	5,424
Denman Flat near Stony Pt Rd	1,980	1,974	1,968	1,918	1,940	1,980	1,981	1,975	1,982	1,981	1,980
Petaluma River at Corona Rd	4,664	4,578	4,545	4,608	4,620	4,663	4,671	4,650	4,660	4,660	4,662
Petaluma River at E Washington St	5,952	5,883	5,858	5,905	5,910	5,939	5,953	5,940	5,946	5,946	5,950

Model Evaluation Point	Peak Water Surface Elevation										
	Detention Basin Scenario					Floodplain Modification Scenario					
	Existing	Willow Brook	Lichau	Marin	Liberty	Lynch	Willow Brook	Lichau	Marin	Liberty	Lynch
	<i>ft</i>	<i>ft</i>	<i>ft</i>	<i>ft</i>	<i>ft</i>	<i>ft</i>	<i>ft</i>	<i>ft</i>	<i>ft</i>	<i>ft</i>	<i>ft</i>
Willow Brook Creek at Ely Rd	49.91	49.69	49.73	49.90	49.90	49.90	49.77	49.88	49.90	49.90	49.90
Denman Flat near Stony Pt Rd	39.07	39.07	39.06	39.03	39.05	39.07	39.08	39.08	39.07	39.07	39.07
Petaluma River at Corona Rd	28.66	28.62	28.60	28.63	28.64	28.66	28.67	28.65	28.66	28.66	28.66
Petaluma River at E Washington St	8.66	8.66	8.66	8.66	8.66	8.62	8.66	8.65	8.66	8.66	8.66

Model Evaluation Point	Peak Flood Depth										
	Detention Basin Scenario					Floodplain Modification Scenario					
	Existing	Willow Brook	Lichau	Marin	Liberty	Lynch	Willow Brook	Lichau	Marin	Liberty	Lynch
	<i>ft</i>	<i>ft</i>	<i>ft</i>	<i>ft</i>	<i>ft</i>	<i>ft</i>	<i>ft</i>	<i>ft</i>	<i>ft</i>	<i>ft</i>	<i>ft</i>
Willow Brook Creek at Ely Rd	16.10	15.88	15.92	16.09	16.09	16.09	15.96	16.07	16.09	16.09	16.09
Denman Flat near Stony Pt Rd	11.22	11.22	11.21	11.18	11.20	11.22	11.23	11.23	11.22	11.22	11.22
Petaluma River at Corona Rd	16.39	16.35	16.33	16.36	16.37	16.39	16.40	16.38	16.39	16.39	16.39
Petaluma River at E Washington St	14.86	14.86	14.86	14.86	14.86	14.82	14.86	14.85	14.86	14.86	14.86

**Peak Velocity**

Model Evaluation Point	Detention Basin Scenario						Floodplain Modification Scenario				
	Existing	Willow Brook	Lichau	Marin	Liberty	Lynch	Willow Brook	Lichau	Marin	Liberty	Lynch
	<i>ft/s</i>	<i>ft/s</i>	<i>ft/s</i>	<i>ft/s</i>	<i>ft/s</i>	<i>ft/s</i>	<i>ft/s</i>	<i>ft/s</i>	<i>ft/s</i>	<i>ft/s</i>	<i>ft/s</i>
Willow Brook Creek at Ely Rd	7.48	7.27	7.30	7.48	7.48	7.48	7.35	7.46	7.48	7.48	7.48
Denman Flat near Stony Pt Rd	1.50	1.50	1.50	1.49	1.49	1.50	1.50	1.53	1.48	1.50	1.50
Petaluma River at Corona Rd	3.69	3.64	3.62	3.66	3.67	3.69	3.69	3.68	3.69	3.69	3.69
Petaluma River at E Washington St	4.79	4.75	4.73	4.76	4.76	4.78	4.79	4.78	4.78	4.78	4.78

**Overbank Flood Duration**

Model Evaluation Point	Detention Basin Scenario						Floodplain Modification Scenario				
	Existing	Willow Brook	Lichau	Marin	Liberty	Lynch	Willow Brook	Lichau	Marin	Liberty	Lynch
	<i>hr</i>	<i>hr</i>	<i>hr</i>	<i>hr</i>	<i>hr</i>	<i>hr</i>	<i>hr</i>	<i>hr</i>	<i>hr</i>	<i>hr</i>	<i>hr</i>
Redwood Hwy at N McDowell Blvd	1.62	1.53	1.43	1.62	1.62	1.62	1.65	1.62	1.62	1.62	1.62
Industrial Ave at Auto Center Dr	4.55	4.48	4.50	4.45	4.47	4.55	4.53	4.52	4.53	4.53	4.55
Corona Rd at N McDowell Blvd	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Petaluma Blvd N at Factory Outlet	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

## 10-Year Model Results – Change from Existing Conditions

### Scenario Model Output: 10-year Flood

Model Evaluation Point	Peak Flow Rate	Change in Peak Flow Rate									
		Detention Basin Scenario					Floodplain Modification Scenario				
		Existing	Willow Brook	Lichau	Marin	Liberty	Lynch	Willow Brook	Lichau	Marin	Liberty
Willow Brook Creek at Ely Rd	5424	-251	-213	0	0	0	-155	-24	0	0	0
Denman Flat near Stony Pt Rd	1980	-6	-12	-62	-41	0	0	-5	2	0	0
Petaluma River at Corona Rd	4664	-85	-118	-56	-43	0	8	-14	-4	-3	-1
Petaluma River at E Washington St	5952	-69	-94	-46	-42	-12	1	-12	-5	-5	-2

Model Evaluation Point	Peak WSE	Change in Peak Water Surface Elevation									
		Detention Basin Scenario					Floodplain Modification Scenario				
		Existing	Willow Brook	Lichau	Marin	Liberty	Lynch	Willow Brook	Lichau	Marin	Liberty
Willow Brook Creek at Ely Rd	49.91	-0.21	-0.18	0.00	0.00	0.00	-0.13	-0.02	0.00	0.00	0.00
Denman Flat near Stony Pt Rd	39.07	-0.01	-0.01	-0.05	-0.03	0.00	0.00	0.00	0.00	0.00	0.00
Petaluma River at Corona Rd	28.66	-0.04	-0.06	-0.03	-0.02	0.00	0.00	-0.01	0.00	0.00	0.00
Petaluma River at E Washington St	8.66	0.00	0.00	0.00	0.00	-0.04	0.00	-0.01	0.00	0.00	0.00

Model Evaluation Point	Peak Depth	Change in Peak Flood Depth									
		Detention Basin Scenario					Floodplain Modification Scenario				
		Existing	Willow Brook	Lichau	Marin	Liberty	Lynch	Willow Brook	Lichau	Marin	Liberty
Willow Brook Creek at Ely Rd	16.10	-0.21	-0.18	0.00	0.00	0.00	-0.13	-0.02	0.00	0.00	0.00
Denman Flat near Stony Pt Rd	11.22	-0.01	-0.01	-0.05	-0.03	0.00	0.00	0.00	0.00	0.00	0.00
Petaluma River at Corona Rd	16.39	-0.04	-0.06	-0.03	-0.02	0.00	0.00	-0.01	0.00	0.00	0.00
Petaluma River at E Washington St	14.86	0.00	0.00	0.00	0.00	-0.04	0.00	-0.01	0.00	0.00	0.00

Model Evaluation Point	Peak Velocity	Change in Peak Velocity									
	Existing	Detention Basin Scenario					Floodplain Modification Scenario				
		Willow Brook	Lichau	Marin	Liberty	Lynch	Willow Brook	Lichau	Marin	Liberty	Lynch
	ft/s	ft/s	ft/s	ft/s	ft/s	ft/s	ft/s	ft/s	ft/s	ft/s	ft/s
Willow Brook Creek at Ely Rd	7.48	-0.21	-0.18	0.00	0.00	0.00	-0.13	-0.02	0.00	0.00	0.00
Denman Flat near Stony Pt Rd	1.50	0.00	0.00	-0.01	-0.01	0.00	0.00	0.03	-0.02	0.00	0.00
Petaluma River at Corona Rd	3.69	-0.05	-0.07	-0.03	-0.02	0.00	0.00	-0.01	0.00	0.00	0.00
Petaluma River at E Washington St	4.79	-0.04	-0.06	-0.03	-0.03	-0.01	0.00	-0.01	-0.01	-0.01	-0.01

Model Evaluation Point	Flood Duration	Change in Overbank Flood Duration									
	Existing	Detention Basin Scenario					Floodplain Modification Scenario				
		Willow Brook	Lichau	Marin	Liberty	Lynch	Willow Brook	Lichau	Marin	Liberty	Lynch
	hr	hr	hr	hr	hr	hr	hr	hr	hr	hr	hr
Redwood Hwy at N McDowell Blvd	1.62	-0.09	-0.19	0.00	0.00	0.00	0.03	0.00	0.00	0.00	0.00
Industrial Ave at Auto Center Dr	4.55	-0.07	-0.05	-0.10	-0.08	0.00	-0.02	-0.03	-0.02	-0.02	0.00
Corona Rd at N McDowell Blvd	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Petaluma Blvd N at Factory Outlet	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

## 100-Year Model Results – Raw Model Output

### Scenario Model Output: 100-year Flood

<b>Model Evaluation Point</b>	<b>Peak Flow Rate</b>										
	<b>Detention Basin Scenario</b>						<b>Floodplain Modification Scenario</b>				
	<b>Existing</b>	<b>Willow Brook</b>	<b>Lichau</b>	<b>Marin</b>	<b>Liberty</b>	<b>Lynch</b>	<b>Willow Brook</b>	<b>Lichau</b>	<b>Marin</b>	<b>Liberty</b>	<b>Lynch</b>
	<i>cfs</i>	<i>cfs</i>	<i>cfs</i>	<i>cfs</i>	<i>cfs</i>	<i>cfs</i>	<i>cfs</i>	<i>cfs</i>	<i>cfs</i>	<i>cfs</i>	<i>cfs</i>
Willow Brook Creek at Ely Rd	7,812	7,379	7,361	7,812	7,812	7,812	7,668	7,768	7,812	7,812	7,812
Denman Flat near Stony Pt Rd	3,089	3,084	3,094	2,897	2,962	3,089	3,063	3,085	3,086	3,091	3,089
Petaluma River at Corona Rd	7,465	7,255	7,234	7,384	7,373	7,459	7,513	7,461	7,460	7,454	7,467
Petaluma River at E Washington St	10,063	9,686	9,702	9,886	9,904	9,956	10,048	10,046	10,057	10,053	10,069

<b>Model Evaluation Point</b>	<b>Peak Water Surface Elevation</b>										
	<b>Detention Basin Scenario</b>						<b>Floodplain Modification Scenario</b>				
	<b>Existing</b>	<b>Willow Brook</b>	<b>Lichau</b>	<b>Marin</b>	<b>Liberty</b>	<b>Lynch</b>	<b>Willow Brook</b>	<b>Lichau</b>	<b>Marin</b>	<b>Liberty</b>	<b>Lynch</b>
	<i>ft</i>	<i>ft</i>	<i>ft</i>	<i>ft</i>	<i>ft</i>	<i>ft</i>	<i>ft</i>	<i>ft</i>	<i>ft</i>	<i>ft</i>	<i>ft</i>
Willow Brook Creek at Ely Rd	52.53	52.26	52.24	52.53	52.53	52.53	52.45	52.51	52.53	52.53	52.53
Denman Flat near Stony Pt Rd	39.95	39.94	39.94	39.87	39.89	39.95	39.95	39.95	39.95	39.95	39.95
Petaluma River at Corona Rd	30.01	29.99	29.98	29.92	29.95	30.01	30.02	30.01	30.01	30.01	30.01
Petaluma River at E Washington St	10.99	10.74	10.75	10.87	10.88	10.90	10.98	10.98	10.98	10.98	10.99

<b>Model Evaluation Point</b>	<b>Peak Flood Depth</b>										
	<b>Detention Basin Scenario</b>						<b>Floodplain Modification Scenario</b>				
	<b>Existing</b>	<b>Willow Brook</b>	<b>Lichau</b>	<b>Marin</b>	<b>Liberty</b>	<b>Lynch</b>	<b>Willow Brook</b>	<b>Lichau</b>	<b>Marin</b>	<b>Liberty</b>	<b>Lynch</b>
	<i>ft</i>	<i>ft</i>	<i>ft</i>	<i>ft</i>	<i>ft</i>	<i>ft</i>	<i>ft</i>	<i>ft</i>	<i>ft</i>	<i>ft</i>	<i>ft</i>
Willow Brook Creek at Ely Rd	18.72	18.45	18.43	18.72	18.72	18.72	18.64	18.70	18.72	18.72	18.72
Denman Flat near Stony Pt Rd	12.10	12.09	12.09	12.02	12.04	12.10	12.10	12.10	12.10	12.10	12.10
Petaluma River at Corona Rd	17.74	17.72	17.71	17.65	17.68	17.74	17.75	17.74	17.74	17.74	17.74
Petaluma River at E Washington St	17.19	16.94	16.95	17.07	17.08	17.10	17.18	17.18	17.18	17.18	17.19

**Peak Velocity**

Model Evaluation Point	Detention Basin Scenario						Floodplain Modification Scenario				
	Existing	Willow Brook	Lichau	Marin	Liberty	Lynch	Willow Brook	Lichau	Marin	Liberty	Lynch
	<i>ft/s</i>	<i>ft/s</i>	<i>ft/s</i>	<i>ft/s</i>	<i>ft/s</i>	<i>ft/s</i>	<i>ft/s</i>	<i>ft/s</i>	<i>ft/s</i>	<i>ft/s</i>	<i>ft/s</i>
Willow Brook Creek at Ely Rd	8.50	8.52	8.53	8.50	8.50	8.50	8.53	8.51	8.50	8.50	8.50
Denman Flat near Stony Pt Rd	1.40	1.40	1.40	1.38	1.39	1.40	1.40	1.46	1.36	1.39	1.40
Petaluma River at Corona Rd	4.86	4.83	4.83	4.77	4.79	4.86	4.86	4.86	4.86	4.86	4.86
Petaluma River at E Washington St	6.49	6.37	6.38	6.44	6.44	6.47	6.49	6.49	6.49	6.49	6.49

**Overbank Flood Duration**

Model Evaluation Point	Detention Basin Scenario						Floodplain Modification Scenario				
	Existing	Willow Brook	Lichau	Marin	Liberty	Lynch	Willow Brook	Lichau	Marin	Liberty	Lynch
	<i>hr</i>	<i>hr</i>	<i>hr</i>	<i>hr</i>	<i>hr</i>	<i>hr</i>	<i>hr</i>	<i>hr</i>	<i>hr</i>	<i>hr</i>	<i>hr</i>
Redwood Hwy at N McDowell Blvd	3.32	3.25	3.17	3.28	3.28	3.30	3.38	3.33	3.32	3.32	3.32
Industrial Ave at Auto Center Dr	6.43	6.43	6.42	6.42	6.37	6.43	6.42	6.43	6.43	6.42	6.43
Corona Rd at N McDowell Blvd	3.22	3.07	3.00	3.18	3.20	3.20	3.25	3.22	3.22	3.22	3.22
Petaluma Blvd N at Factory Outlet	5.12	4.90	4.88	4.90	4.93	5.10	5.08	5.10	5.10	5.10	5.10

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**- 100-Year Model Results – Change from Existing Conditions**

**Scenario Model Output: 100-year Flood**

Model Evaluation Point	Peak Flow Rate	Change in Peak Flow Rate									
		Detention Basin Scenario					Floodplain Modification Scenario				
		Existing	Willow Brook	Lichau	Marin	Liberty	Lynch	Willow Brook	Lichau	Marin	Liberty
Willow Brook Creek at Ely Rd	7,812	-433	-451	0	0	0	-143	-43	0	0	0
Denman Flat near Stony Pt Rd	3,089	-5	4	-192	-127	0	-26	-4	-4	1	0
Petaluma River at Corona Rd	7,465	-210	-231	-81	-92	-7	47	-4	-6	-12	2
Petaluma River at E Washington St	10,063	-377	-361	-178	-159	-107	-15	-17	-6	-11	5

Model Evaluation Point	Peak WSE	Change in Peak Water Surface Elevation									
		Detention Basin Scenario					Floodplain Modification Scenario				
		Existing	Willow Brook	Lichau	Marin	Liberty	Lynch	Willow Brook	Lichau	Marin	Liberty
Willow Brook Creek at Ely Rd	52.53	-0.28	-0.30	0.00	0.00	0.00	-0.08	-0.02	0.00	0.00	0.00
Denman Flat near Stony Pt Rd	39.95	-0.01	-0.01	-0.08	-0.06	0.00	0.00	0.00	0.00	0.00	0.00
Petaluma River at Corona Rd	30.01	-0.02	-0.03	-0.09	-0.06	0.00	0.00	0.00	0.00	0.00	0.00
Petaluma River at E Washington St	10.99	-0.25	-0.24	-0.12	-0.11	-0.09	-0.01	-0.01	0.00	-0.01	0.01

Model Evaluation Point	Peak Depth	Change in Peak Flood Depth									
		Detention Basin Scenario					Floodplain Modification Scenario				
		Existing	Willow Brook	Lichau	Marin	Liberty	Lynch	Willow Brook	Lichau	Marin	Liberty
Willow Brook Creek at Ely Rd	18.72	-0.28	-0.30	0.00	0.00	0.00	-0.08	-0.02	0.00	0.00	0.00
Denman Flat near Stony Pt Rd	12.10	-0.01	-0.01	-0.08	-0.06	0.00	0.00	0.00	0.00	0.00	0.00
Petaluma River at Corona Rd	17.74	-0.02	-0.03	-0.09	-0.06	0.00	0.00	0.00	0.00	0.00	0.00
Petaluma River at E Washington St	17.19	-0.25	-0.24	-0.12	-0.11	-0.09	-0.01	-0.01	0.00	-0.01	0.00

Model Evaluation Point	Peak Velocity	Change in Peak Velocity									
	Existing	Detention Basin Scenario					Floodplain Modification Scenario				
		Willow Brook	Lichau	Marin	Liberty	Lynch	Willow Brook	Lichau	Marin	Liberty	Lynch
	ft/s	ft/s	ft/s	ft/s	ft/s	ft/s	ft/s	ft/s	ft/s	ft/s	ft/s
Willow Brook Creek at Ely Rd	8.50	0.02	0.03	0.00	0.00	0.00	0.03	0.01	0.00	0.00	0.00
Denman Flat near Stony Pt Rd	1.40	0.00	0.00	-0.02	-0.01	0.00	0.00	0.06	-0.04	-0.01	0.00
Petaluma River at Corona Rd	4.86	-0.03	-0.03	-0.09	-0.07	0.00	0.00	0.00	0.00	0.00	0.00
Petaluma River at E Washington St	6.49	-0.12	-0.11	-0.05	-0.05	-0.02	0.00	0.00	0.00	0.00	0.00

Model Evaluation Point	Flood Duration	Change in Overbank Flood Duration									
	Existing	Detention Basin Scenario					Floodplain Modification Scenario				
		Willow Brook	Lichau	Marin	Liberty	Lynch	Willow Brook	Lichau	Marin	Liberty	Lynch
	hr	hr	hr	hr	hr	hr	hr	hr	hr	hr	hr
Redwood Hwy at N McDowell Blvd	3.32	-0.07	-0.15	-0.04	-0.04	-0.02	0.06	0.01	0.00	0.00	0.00
Industrial Ave at Auto Center Dr	6.43	0.00	-0.01	-0.01	-0.06	0.00	-0.01	0.00	0.00	-0.01	0.00
Corona Rd at N McDowell Blvd	3.22	-0.15	-0.22	-0.04	-0.02	-0.02	0.03	0.00	0.00	0.00	0.00
Petaluma Blvd N at Factory Outlet	5.12	-0.22	-0.24	-0.22	-0.19	-0.02	-0.04	-0.02	-0.02	-0.02	-0.02

## **APPENDIX D: MODEL RESULTS – LOCAL IMPACTS**

### Scenario Model Output: 10-year Flood

Criteria	Change in Peak Flow Rate									
	Willow Brook		Lichau		Marin		Liberty		Lynch	
	Detention Basin	Floodplain Modification	Detention Basin	Floodplain Modification	Detention Basin	Floodplain Modification	Detention Basin	Floodplain Modification	Detention Basin	Floodplain Modification
<b>Peak Flow Rate</b>										
Existing Upstream (cfs)	1,713		2,889		950		202		1,266	
With Project (cfs)	1,713	1,716	2,889	2,894	950	951	202	202	1,266	1,266
<b>Delta (cfs)</b>	<b>0</b>	<b>3</b>	<b>0</b>	<b>5</b>	<b>0</b>	<b>2</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>0</b>
Existing Downstream (cfs)	1,631		2,970		1,302		244		808	
With Project (cfs)	1,369	1,496	2,735	2,958	1,106	1,291	101	206	677	810
<b>Delta (cfs)</b>	<b>-262</b>	<b>-135</b>	<b>-234</b>	<b>-12</b>	<b>-196</b>	<b>-11</b>	<b>-142</b>	<b>-38</b>	<b>-131</b>	<b>2</b>

Criteria	Change in Peak Water Surface Elevation									
	Willow Brook		Lichau		Marin		Liberty		Lynch	
	Detention Basin	Floodplain Modification	Detention Basin	Floodplain Modification	Detention Basin	Floodplain Modification	Detention Basin	Floodplain Modification	Detention Basin	Floodplain Modification
<b>Water Surface Elevation</b>										
Existing Upstream (ft)	100.8		77.6		50.5		82.0		125.3	
With Project (ft)	100.8	99.9	77.6	77.4	50.5	50.2	82.0	81.7	125.3	125.3
<b>Delta (ft)</b>	<b>0.0</b>	<b>-0.9</b>	<b>0.0</b>	<b>-0.2</b>	<b>0.0</b>	<b>-0.3</b>	<b>0.0</b>	<b>-0.2</b>	<b>0.0</b>	<b>0.0</b>
Existing Downstream (ft)	81.2		62.9		45.7		52.5		59.1	
With Project (ft)	81.0	81.1	62.8	62.9	45.5	45.6	52.0	52.4	58.4	59.1
<b>Delta (ft)</b>	<b>-0.3</b>	<b>-0.2</b>	<b>-0.1</b>	<b>0.0</b>	<b>-0.2</b>	<b>0.0</b>	<b>-0.4</b>	<b>-0.1</b>	<b>-0.7</b>	<b>0.0</b>

Criteria	Change in Peak Flood Depth									
	Willow Brook		Lichau		Marin		Liberty		Lynch	
	Detention Basin	Floodplain Modification	Detention Basin	Floodplain Modification	Detention Basin	Floodplain Modification	Detention Basin	Floodplain Modification	Detention Basin	Floodplain Modification
<b>Peak Flood Depth</b>										
Existing Upstream (ft)	7.2		12.0		3.5		3.6		5.6	
With Project (ft)	7.2	6.4	12.0	11.8	3.5	3.2	3.6	3.4	5.7	5.6
<b>Delta (ft)</b>	<b>0.0</b>	<b>-0.9</b>	<b>0.0</b>	<b>-0.2</b>	<b>0.0</b>	<b>-0.3</b>	<b>0.0</b>	<b>-0.2</b>	<b>0.0</b>	<b>0.0</b>
Existing Downstream (ft)	6.1		10.1		4.1		2.4		7.5	
With Project (ft)	5.8	5.9	10.0	10.1	3.9	4.1	2.0	2.4	6.8	7.5
<b>Delta (ft)</b>	<b>-0.3</b>	<b>-0.2</b>	<b>-0.1</b>	<b>0.0</b>	<b>-0.2</b>	<b>0.0</b>	<b>-0.4</b>	<b>-0.1</b>	<b>-0.7</b>	<b>0.0</b>

Criteria	Change in Peak Velocity									
	Willow Brook		Lichau		Marin		Liberty		Lynch	
	Detention Basin	Floodplain Modification	Detention Basin	Floodplain Modification	Detention Basin	Floodplain Modification	Detention Basin	Floodplain Modification	Detention Basin	Floodplain Modification
<b>Peak Velocity</b>										
Existing Upstream (ft/s)	5.7		9.1		3.2		3.0		8.8	
With Project (ft/s)	5.7	7.1	9.1	12.5	3.2	4.0	3.0	3.6	8.8	8.8
<b>Delta (ft/s)</b>	<b>0.0</b>	<b>1.3</b>	<b>0.0</b>	<b>3.4</b>	<b>0.0</b>	<b>0.8</b>	<b>0.0</b>	<b>0.5</b>	<b>0.0</b>	<b>0.0</b>
Existing Downstream (ft/s)	7.4		7.0		2.9		2.0		3.2	
With Project (ft/s)	7.1	7.2	6.9	7.0	2.8	3.0	1.2	1.9	3.2	3.3
<b>Delta (ft/s)</b>	<b>-0.3</b>	<b>-0.1</b>	<b>-0.1</b>	<b>0.0</b>	<b>-0.2</b>	<b>0.0</b>	<b>-0.7</b>	<b>-0.1</b>	<b>0.0</b>	<b>0.2</b>

### Scenario Model Output: 100-year Flood

Criteria	Change in Peak Flow Rate									
	Willow Brook		Lichau		Marin		Liberty		Lynch	
	Detention Basin	Floodplain Modification	Detention Basin	Floodplain Modification	Detention Basin	Floodplain Modification	Detention Basin	Floodplain Modification	Detention Basin	Floodplain Modification
<b>Peak Flow Rate</b>										
Existing Upstream (cfs)	2,795		4,213		1,568		436		2,109	
With Project (cfs)	2,795	2,797	4,210	4,214	1,568	1,570	436	435	2,114	2,109
<b>Delta (cfs)</b>	<b>0</b>	<b>2</b>	<b>-3</b>	<b>1</b>	<b>1</b>	<b>2</b>	<b>0</b>	<b>0</b>	<b>5</b>	<b>0</b>
Existing Downstream (cfs)	2,502		4,331		2,295		541		1,801	
With Project (cfs)	1,721	2,203	3,824	4,285	1,920	2,283	126	488	1,223	1,782
<b>Delta (cfs)</b>	<b>-781</b>	<b>-299</b>	<b>-506</b>	<b>-46</b>	<b>-376</b>	<b>-12</b>	<b>-414</b>	<b>-53</b>	<b>-578</b>	<b>-20</b>

Criteria	Change in Peak Water Surface Elevation									
	Willow Brook		Lichau		Marin		Liberty		Lynch	
	Detention Basin	Floodplain Modification	Detention Basin	Floodplain Modification	Detention Basin	Floodplain Modification	Detention Basin	Floodplain Modification	Detention Basin	Floodplain Modification
<b>Water Surface Elevation</b>										
Existing Upstream (ft)	102.1		78.3		51.0		82.5		125.7	
With Project (ft)	102.0	100.9	78.3	78.2	51.0	50.7	82.5	82.3	125.7	125.7
<b>Delta (ft)</b>	<b>0.0</b>	<b>-1.2</b>	<b>0.0</b>	<b>-0.1</b>	<b>0.0</b>	<b>-0.3</b>	<b>0.0</b>	<b>-0.1</b>	<b>0.0</b>	<b>0.0</b>
Existing Downstream (ft)	81.9		63.5		46.3		52.8		62.8	
With Project (ft)	81.4	81.7	63.3	63.4	46.1	46.3	52.1	52.8	61.2	62.8
<b>Delta (ft)</b>	<b>-0.5</b>	<b>-0.2</b>	<b>-0.2</b>	<b>0.0</b>	<b>-0.2</b>	<b>0.0</b>	<b>-0.7</b>	<b>-0.1</b>	<b>-1.6</b>	<b>0.0</b>

Criteria	Change in Peak Flood Depth									
	Willow Brook		Lichau		Marin		Liberty		Lynch	
	Detention Basin	Floodplain Modification	Detention Basin	Floodplain Modification	Detention Basin	Floodplain Modification	Detention Basin	Floodplain Modification	Detention Basin	Floodplain Modification
<b>Peak Flood Depth</b>										
Existing Upstream (ft)	8.6		12.7		4.0		4.1		6.0	
With Project (ft)	8.5	7.4	12.7	12.7	4.0	3.7	4.1	4.0	6.0	6.0
<b>Delta (ft)</b>	<b>0.0</b>	<b>-1.2</b>	<b>0.0</b>	<b>-0.1</b>	<b>0.0</b>	<b>-0.3</b>	<b>0.0</b>	<b>-0.1</b>	<b>0.0</b>	<b>0.0</b>
Existing Downstream (ft)	6.7		10.7		4.7		2.8		11.2	
With Project (ft)	6.2	6.5	10.5	10.6	4.5	4.7	2.1	2.7	9.6	11.2
<b>Delta (ft)</b>	<b>-0.5</b>	<b>-0.2</b>	<b>-0.2</b>	<b>0.0</b>	<b>-0.2</b>	<b>0.0</b>	<b>-0.7</b>	<b>-0.1</b>	<b>-1.6</b>	<b>0.0</b>

Criteria	Change in Peak Velocity									
	Willow Brook		Lichau		Marin		Liberty		Lynch	
	Detention Basin	Floodplain Modification	Detention Basin	Floodplain Modification	Detention Basin	Floodplain Modification	Detention Basin	Floodplain Modification	Detention Basin	Floodplain Modification
<b>Peak Velocity</b>										
Existing Upstream (ft/s)	7.2		9.4		3.5		4.0		8.8	
With Project (ft/s)	7.2	9.1	9.4	12.6	3.6	4.5	4.0	4.4	8.8	8.8
<b>Delta (ft/s)</b>	<b>0.0</b>	<b>1.9</b>	<b>0.0</b>	<b>3.3</b>	<b>0.0</b>	<b>1.0</b>	<b>0.0</b>	<b>0.4</b>	<b>0.0</b>	<b>0.0</b>
Existing Downstream (ft/s)	8.0		7.5		3.5		2.2		3.2	
With Project (ft/s)	7.5	7.8	7.3	7.5	3.3	3.5	1.4	2.2	3.2	3.3
<b>Delta (ft/s)</b>	<b>-0.5</b>	<b>-0.2</b>	<b>-0.2</b>	<b>0.0</b>	<b>-0.2</b>	<b>0.1</b>	<b>-0.8</b>	<b>-0.1</b>	<b>0.0</b>	<b>0.1</b>

## **APPENDIX E:      DETAILED CONCEPT SCORING AND WEIGHTING**

## 10-Year Model Results – Concept Scoring

### Scenario Model Output: 10-year Flood

Location	Peak Flow Rate	Change in Peak Flow Rate									
		Detention Basin Scenario					Floodplain Modification Scenario				
		Willow Brook	Lichau	Marin	Liberty	Lynch	Willow Brook	Lichau	Marin	Liberty	Lynch
Existing	Score	Score	Score	Score	Score	Score	Score	Score	Score	Score	
Willow Brook Creek at Ely Rd	<i>cfs</i> 5424	6	6	2	2	2	4	4	2	2	2
Denman Flat near Stony Pt Rd	1980	4	4	4	4	2	2	4	2	2	2
Petaluma River at Corona Rd	4664	4	4	4	4	2	2	4	2	2	2
Petaluma River at E Washington St	5952	4	4	4	4	4	2	4	4	4	2

Location	Peak WSE	Change in Peak Water Surface Elevation									
		Detention Basin Scenario					Floodplain Modification Scenario				
		Willow Brook	Lichau	Marin	Liberty	Lynch	Willow Brook	Lichau	Marin	Liberty	Lynch
Existing	Score	Score	Score	Score	Score	Score	Score	Score	Score	Score	
Willow Brook Creek at Ely Rd	<i>ft</i> 49.91	3	3	1	1	1	2	2	1	1	1
Denman Flat near Stony Pt Rd	39.07	2	2	2	2	1	1	1	1	1	1
Petaluma River at Corona Rd	28.66	2	2	2	2	1	1	2	1	1	1
Petaluma River at E Washington St	8.66	1	1	1	1	2	1	2	1	1	1

Location	Peak Depth	Change in Peak Flood Depth									
		Detention Basin Scenario					Floodplain Modification Scenario				
		Willow Brook	Lichau	Marin	Liberty	Lynch	Willow Brook	Lichau	Marin	Liberty	Lynch
Existing	Score	Score	Score	Score	Score	Score	Score	Score	Score	Score	
Willow Brook Creek at Ely Rd	<i>ft</i> 16.10	3	3	1	1	1	2	2	1	1	1
Denman Flat near Stony Pt Rd	11.22	2	2	2	2	1	1	1	1	1	1
Petaluma River at Corona Rd	16.39	2	2	2	2	1	1	2	1	1	1
Petaluma River at E Washington St	14.86	1	1	1	1	2	1	2	1	1	1



Location	Peak Velocity	Change in Peak Velocity									
		Detention Basin Scenario					Floodplain Modification Scenario				
		Willow Brook	Lichau	Marin	Liberty	Lynch	Willow Brook	Lichau	Marin	Liberty	Lynch
Existing	Score	Score	Score	Score	Score	Score	Score	Score	Score	Score	
Willow Brook Creek at Ely Rd	7.48	3	3	1	1	1	2	2	1	1	1
Denman Flat near Stony Pt Rd	1.50	1	1	2	2	1	1	1	2	1	1
Petaluma River at Corona Rd	3.69	2	2	2	2	1	1	2	1	1	1
Petaluma River at E Washington St	4.79	2	2	2	2	2	1	2	2	2	2

Location	Flood Duration	Change in Overbank Flood Duration									
		Detention Basin Scenario					Floodplain Modification Scenario				
		Willow Brook	Lichau	Marin	Liberty	Lynch	Willow Brook	Lichau	Marin	Liberty	Lynch
Existing	Score	Score	Score	Score	Score	Score	Score	Score	Score	Score	
Redwood Hwy at N McDowell Blvd	1.62	4	6	2	2	2	2	2	2	2	2
Industrial Ave at Auto Center Dr	4.55	4	4	4	4	2	4	4	4	4	2
Corona Rd at N McDowell Blvd	0.00	2	2	2	2	2	2	2	2	2	2
Petaluma Blvd N at Factory Outlet	0.00	2	2	2	2	2	2	2	2	2	2

### 100-Year Model Results – Concept Scoring

#### Scenario Model Output: 100-year Flood

Location	Peak Flow Rate	Change in Peak Flow Rate									
		Detention Basin Scenario					Floodplain Modification Scenario				
		Willow Brook	Lichau	Marin	Liberty	Lynch	Willow Brook	Lichau	Marin	Liberty	Lynch
Existing	Score	Score	Score	Score	Score	Score	Score	Score	Score	Score	
Willow Brook Creek at Ely Rd	7,812	6	6	2	2	2	4	4	2	2	2
Denman Flat near Stony Pt Rd	3,089	2	2	4	4	2	4	2	2	2	2
Petaluma River at Corona Rd	7,465	4	4	4	4	2	2	2	2	4	2
Petaluma River at E Washington St	10,063	6	4	4	4	4	4	4	2	4	2

Location	Peak WSE	Change in Peak Water Surface Elevation									
		Detention Basin Scenario					Floodplain Modification Scenario				
		Willow Brook	Lichau	Marin	Liberty	Lynch	Willow Brook	Lichau	Marin	Liberty	Lynch
Existing	Score	Score	Score	Score	Score	Score	Score	Score	Score	Score	
Willow Brook Creek at Ely Rd	52.53	3	3	1	1	1	2	2	1	1	1
Denman Flat near Stony Pt Rd	39.95	2	2	2	2	1	2	2	2	1	1
Petaluma River at Corona Rd	30.01	2	2	2	2	1	1	2	2	1	1
Petaluma River at E Washington St	10.99	2	2	2	2	2	2	2	2	2	1

Location	Peak Depth	Change in Peak Flood Depth									
		Detention Basin Scenario					Floodplain Modification Scenario				
		Willow Brook	Lichau	Marin	Liberty	Lynch	Willow Brook	Lichau	Marin	Liberty	Lynch
Existing	Score	Score	Score	Score	Score	Score	Score	Score	Score	Score	
Willow Brook Creek at Ely Rd	18.72	3	3	1	1	1	2	2	1	1	1
Denman Flat near Stony Pt Rd	12.10	2	2	2	2	1	1	1	1	1	1
Petaluma River at Corona Rd	17.74	2	2	2	2	1	1	1	1	1	1
Petaluma River at E Washington St	17.19	2	2	2	2	2	2	2	1	2	1

Location	Peak Velocity	Change in Peak Velocity									
		Detention Basin Scenario					Floodplain Modification Scenario				
		Willow Brook	Lichau	Marin	Liberty	Lynch	Willow Brook	Lichau	Marin	Liberty	Lynch
Existing	Score	Score	Score	Score	Score	Score	Score	Score	Score	Score	
	<i>ft/s</i>										
Willow Brook Creek at Ely Rd	8.50	1	1	1	1	1	1	1	1	1	
Denman Flat near Stony Pt Rd	1.40	1	1	2	2	1	1	1	2	2	
Petaluma River at Corona Rd	4.86	2	2	2	2	1	1	1	1	1	
Petaluma River at E Washington St	6.49	3	3	2	2	2	1	1	1	1	

Location	Flood Duration	Change in Overbank Flood Duration									
		Detention Basin Scenario					Floodplain Modification Scenario				
		Willow Brook	Lichau	Marin	Liberty	Lynch	Willow Brook	Lichau	Marin	Liberty	Lynch
Existing	Score	Score	Score	Score	Score	Score	Score	Score	Score	Score	
	<i>hr</i>										
Redwood Hwy at N McDowell Blvd	3.32	4	4	4	4	4	2	2	2	2	
Industrial Ave at Auto Center Dr	6.43	2	4	4	4	2	4	2	2	4	
Corona Rd at N McDowell Blvd	3.22	4	6	4	4	4	2	2	2	2	
Petaluma Blvd N at Factory Outlet	5.12	6	6	6	4	4	4	4	4	4	

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### Concept Scoring and Ranking Overview

Scenario Model Output: 10-year Flood										
	Detention Basin Scenario					Floodplain Modification Scenario				
	Willow Brook	Lichau	Marin	Liberty	Lynch	Willow Brook	Lichau	Marin	Liberty	Lynch
Change in Peak Flow Rate	18	18	14	14	10	10	16	10	10	8
Change in Peak Water Surface Elevation	8	8	6	6	5	5	7	4	4	4
Change in Peak Flood Depth	8	8	6	6	5	5	7	4	4	4
Change in Peak Velocity	8	8	7	7	5	5	7	6	5	5
Change in Overbank Flood Duration	12	14	10	10	8	10	10	10	10	8
<b>Total</b>	<b>54</b>	<b>56</b>	<b>43</b>	<b>43</b>	<b>33</b>	<b>35</b>	<b>47</b>	<b>34</b>	<b>33</b>	<b>29</b>
Max Score	84	84	84	84	84	84	84	84	84	84
Scenario Model Output: 100-year Flood										
	Detention Basin Scenario					Floodplain Modification Scenario				
	Willow Brook	Lichau	Marin	Liberty	Lynch	Willow Brook	Lichau	Marin	Liberty	Lynch
Change in Peak Flow Rate	18	16	14	14	10	14	12	8	12	8
Change in Peak Water Surface Elevation	9	9	7	7	5	7	8	7	5	4
Change in Peak Flood Depth	9	9	7	7	5	6	6	4	5	4
Change in Peak Velocity	7	7	7	7	5	4	4	5	5	4
Change in Overbank Flood Duration	16	20	18	16	14	12	10	10	12	10
<b>Total</b>	<b>59</b>	<b>61</b>	<b>53</b>	<b>51</b>	<b>39</b>	<b>43</b>	<b>40</b>	<b>34</b>	<b>39</b>	<b>30</b>
Max Score	84	84	84	84	84	84	84	84	84	84
Summary										
	Detention Basin Scenario					Floodplain Modification Scenario				
	Willow Brook	Lichau	Marin	Liberty	Lynch	Willow Brook	Lichau	Marin	Liberty	Lynch
<b>10-Year</b>	<b>54</b>	<b>56</b>	<b>43</b>	<b>43</b>	<b>33</b>	<b>35</b>	<b>47</b>	<b>34</b>	<b>33</b>	<b>29</b>
<b>100-Year</b>	<b>59</b>	<b>61</b>	<b>53</b>	<b>51</b>	<b>39</b>	<b>43</b>	<b>40</b>	<b>34</b>	<b>39</b>	<b>30</b>
<b>Total</b>	<b>113</b>	<b>117</b>	<b>96</b>	<b>94</b>	<b>72</b>	<b>78</b>	<b>87</b>	<b>68</b>	<b>72</b>	<b>59</b>
Max Score	168	168	168	168	168	168	168	168	168	168
Rank										
<b>10-Year</b>	<b>2</b>	<b>1</b>	<b>4</b>	<b>4</b>	<b>8</b>	<b>6</b>	<b>3</b>	<b>7</b>	<b>8</b>	<b>10</b>
<b>100-Year</b>	<b>2</b>	<b>1</b>	<b>3</b>	<b>4</b>	<b>7</b>	<b>5</b>	<b>6</b>	<b>9</b>	<b>7</b>	<b>10</b>
<b>Total</b>	<b>2</b>	<b>1</b>	<b>3</b>	<b>4</b>	<b>7</b>	<b>6</b>	<b>5</b>	<b>9</b>	<b>7</b>	<b>10</b>

### Concept Scoring and Ranking by Location

#### Scenario Model Output: 10-year Flood Score

	Detention Basin Scenario					Floodplain Modification Scenario				
	Willow Brook	Lichau	Marin	Liberty	Lynch	Willow Brook	Lichau	Marin	Liberty	Lynch
Willow Brook Creek at Ely Rd	15	15	5	5	5	10	10	5	5	5
Denman Flat near Stony Pt Rd	9	9	10	10	5	5	7	6	5	5
Petaluma River at Corona Rd	10	10	10	10	5	5	10	5	5	5
Petaluma River at E Washington St	8	8	8	8	10	5	10	8	8	6
Redwood Hwy at N McDowell Blvd	4	6	2	2	2	2	2	2	2	2
Industrial Ave at Auto Center Dr	4	4	4	4	2	4	4	4	4	2
Corona Rd at N McDowell Blvd	2	2	2	2	2	2	2	2	2	2
Petaluma Blvd N at Factory Outlet	2	2	2	2	2	2	2	2	2	2
<b>Total</b>	<b>54</b>	<b>56</b>	<b>43</b>	<b>43</b>	<b>33</b>	<b>35</b>	<b>47</b>	<b>34</b>	<b>33</b>	<b>29</b>

#### Scenario Model Output: 100-year Flood Score

	Detention Basin Scenario					Floodplain Modification Scenario				
	Willow Brook	Lichau	Marin	Liberty	Lynch	Willow Brook	Lichau	Marin	Liberty	Lynch
Willow Brook Creek at Ely Rd	13	13	5	5	5	9	9	5	5	5
Denman Flat near Stony Pt Rd	7	7	10	10	5	8	6	7	6	5
Petaluma River at Corona Rd	10	10	10	10	5	5	6	6	7	5
Petaluma River at E Washington St	13	11	10	10	10	9	9	6	9	5
Redwood Hwy at N McDowell Blvd	4	4	4	4	4	2	2	2	2	2
Industrial Ave at Auto Center Dr	2	4	4	4	2	4	2	2	4	2
Corona Rd at N McDowell Blvd	4	6	4	4	4	2	2	2	2	2
Petaluma Blvd N at Factory Outlet	6	6	6	4	4	4	4	4	4	4
<b>Total</b>	<b>59</b>	<b>61</b>	<b>53</b>	<b>51</b>	<b>39</b>	<b>43</b>	<b>40</b>	<b>34</b>	<b>39</b>	<b>30</b>

#### Total Score

	Detention Basin Scenario					Floodplain Modification Scenario				
	Willow Brook	Lichau	Marin	Liberty	Lynch	Willow Brook	Lichau	Marin	Liberty	Lynch
Willow Brook Creek at Ely Rd	28	28	10	10	10	19	19	10	10	10
Denman Flat near Stony Pt Rd	16	16	20	20	10	13	13	13	11	10
Petaluma River at Corona Rd	20	20	20	20	10	10	16	11	12	10
Petaluma River at E Washington St	21	19	18	18	20	14	19	14	17	11
Redwood Hwy at N McDowell Blvd	8	10	6	6	6	4	4	4	4	4
Industrial Ave at Auto Center Dr	6	8	8	8	4	8	6	6	8	4
Corona Rd at N McDowell Blvd	6	8	6	6	6	4	4	4	4	4
Petaluma Blvd N at Factory Outlet	8	8	8	6	6	6	6	6	6	6
<b>Total</b>	<b>113</b>	<b>117</b>	<b>96</b>	<b>94</b>	<b>72</b>	<b>78</b>	<b>87</b>	<b>68</b>	<b>72</b>	<b>59</b>

	Total Rank									
<b>Willow Brook Creek at Ely Rd</b>	1	1	5	5	5	3	3	5	5	5
<b>Denman Flat near Stony Pt Rd</b>	3	3	1	1	9	5	5	5	8	9
<b>Petaluma River at Corona Rd</b>	1	1	1	1	8	8	5	7	6	8
<b>Petaluma River at E Washington St</b>	1	3	5	5	2	8	3	8	7	10
<b>Redwood Hwy at N McDowell Blvd</b>	2	1	3	3	3	6	6	6	6	6
<b>Industrial Ave at Auto Center Dr</b>	6	1	1	1	9	1	6	6	1	9
<b>Corona Rd at N McDowell Blvd</b>	2	1	2	2	2	6	6	6	6	6
<b>Petaluma Blvd N at Factory Outlet</b>	1	1	1	4	4	4	4	4	4	4
<b>Total</b>	<b>2</b>	<b>1</b>	<b>3</b>	<b>4</b>	<b>7</b>	<b>6</b>	<b>5</b>	<b>9</b>	<b>7</b>	<b>10</b>