1 EXECUTIVE SUMMARY

The Watershed Program of the Marin County Department of Public Works (MCDPW) conducted this Novato Creek Hydraulic Study (the “NHS”) to identify and evaluate a suite of feasible alternatives to reduce Novato Creek flood hazards and on-going sediment management effort and cost. Alternatives are to be designed in a manner that protects, if not enhances, sensitive habitat and species (particularly steelhead and Ca. Ridgway’s Rail) that reside in Novato creeks and baylands. This report presents the suite of recommended alternatives, and preliminary numerical modeling analyses used to evaluate the efficacy of recommended actions.

Kamman Hydrology & Engineering, Inc. (KHE) led the NHS study, with support from a consultant team which included WRECO Consultants (WRECO) and Dynamic Solutions International (DSI). WRECO and DSI conducted modeling analysis in the watershed and bayland respectively. MCDPW staff provided community and stakeholder outreach and coordination, and design storm and hydrology (rainfall/runoff) analysis. This NHS alternatives analysis is supported by prior NHS study phases,1 and by prior MCDPW flood and bayland studies and management actions. The focus of the

The Marin County Flood Control and Water Conservation District (District) and the Novato Flood Control Zone 1 Advisory Board have a long history of successful flood hazard mitigation work via the Novato Creek Flood Control Project (MCDPW, 1984). Multiple flood control projects have been implemented in the corridor to maximize flood conveyance and stabilize eroding banks in Novato Creek between Grant Ave. and Diablo Ave. The District dredges aggrading sediment between Diablo Ave. and the Sonoma Marin Area Regional Transit (SMART) Bridge every four years to maintain channel conveyance for the 50 year storm event. Routine channel maintenance also includes clearing trash and overgrown vegetation from the channel.

This study is a continuation of these efforts to further improve flood protection efficiencies and reduce the ecological impacts of flood and sediment management. The focus of the study is on flood protection improvements to the current Novato Flood Control Project which maintain 50 year flood protection. A secondary goal is to reduce sediment aggradation and the associated dredging costs, which improving habitat for special status in the area. Opportunities for improvement are greatest in Novato Baylands where MCDPW owns and manages both flood protection levees and most of the adjacent undeveloped bayland basin. This NHS study uses a watershed approach, and looks more broadly to identify opportunities for flood hazard mitigation both upstream and downstream of downtown Novato. While there is a good basis of information in prior flood control work in these downstream reaches. This is the first effort to characterize and evaluate

1 Prior site assessment phases characterized watershed conditions and configured/calibrated numerical models which predict Novato creek, bayland and overbank flows from Stafford Dam to San Pablo Bay (KHE, 2014).
opportunities for flood control improvement upstream of Grant Avenue (the limit of prior Flood Control study). The NHS study has the following objectives:

- Evaluates the impacts and recommends mitigation measures to maintain or improve the flood conveyance capacity now and in the future assuming that sea level rise and increasing storm intensity will increase watershed flood hazards;
- Integrates consideration of riparian corridor as habitat for fish and wildlife, and identifies actions which concurrently support the ecological values of the watershed.
- Considers geomorphic processes (sediment transport, deposition and scour) in the design and evaluation of flood mitigation in an effort to reduce channel maintenance costs and impacts;
- Defines and evaluates measures to reduce the impacts associated with overbank flooding;
- Evaluates tidal influences on low lying reaches of Novato and Warner creeks below Seventh St./Tamalpais Ave.; and,
- Evaluates actions in the tidal baylands to reduce dredge maintenance by expanding the creek corridor and restoring subsided tidal wetland to store aggrading sediment.

Current conditions in Novato’s creek corridors reflect changes due to urbanization. The prior existing conditions assessment (KHE, 2014) and monitoring found that despite successful efforts to maximize conveyance, both Novato Creek and Warner creek currently flow at or near bankfull in a 10-20 year event. Warner Creek (from McClay Ave. downstream) and Novato Creek (Grant Ave. to Diablo Ave.) are the focus of ongoing work to provide 50 year flood conveyance with minimal out of channel flooding that doesn’t inundate residential and commercial living space. There are several reasons why Lower Novato Creek may not contain a 50 year design flow including: 1) updated MCDPW/WRECO generated design storm estimates reflect the more recent, larger magnitude storm events; and 2) the more detailed hydraulic modeling in the watershed characterizes both instream and overbank flows more accurately, providing a better accounting of the water that flows out of bank but returns to the same drainage. Because flooding is anticipated during large storm events, the NHS study sought to identify and evaluate measures which reduce the adverse impacts of overbank flooding.

The NHS uses a consensus based approach supported by public and private stakeholders to identify and select study alternatives. MCDPW defined a list of recommended project “elements” based on watershed existing conditions, and opportunities/constraints assessments. After identifying the

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2 An “element” is a group of actions which satisfy identified NHS study goal (e.g. reduce flooding in known location).
elements, the team worked with project stakeholders\(^3\) to define ranking criteria which considered flood control, implementation feasibility, ecological impact/benefit and cost. Stakeholder and public meetings were held to develop consensus on the elements, evaluation criteria and ranking. KHE then used these criteria to evaluate, rank and group elements to create three (3) recommended alternatives that reflect stakeholder’s priorities, and the technical study team’s understanding of current watershed and bayland flood hydraulics\(^4\).

Alternatives are evaluated via numerical models which permit comparison of Existing and Alternative flood impacts. The study focuses on flood conditions associated with a 10-year (yr.), 50 yr. and 100 yr. storms, and the effects of 12” and 36” of sea level rise (SLR) in San Pablo Bay. Evaluation of creek and bayland actions together is necessary for the NHS study because the City of Novato is susceptible to flooding from watershed runoff (upstream), which is made worse by high tides (downstream) that reduce City drainage capacity. As a result, actions are required to address flooding in Novato from both upstream and downstream sources. To facilitate planning and implementation, the alternatives are organized into those elements recommended for implementation in SHORT (5-10 years), MEDIUM (10-15 yr.) and LONG (20+ yr.) term action plans.

1.1 Summary of Study Alternatives:

The overarching goal of the study is to reduce peak flood water surface elevations, and increase flood and sediment conveyance, while improving ecological conditions in the corridor. Creek elements decrease flooding by adding Stafford Dam, floodplain and detention storage, and by improving drainage in areas where flooding occurs. Baylands elements expand the currently leveed floodplain using storm water spillways or breaching (via levee removal) to tidal basins adjacent to Novato Creek. Each of the recommended study alternatives (Short, Medium and Long) creates an incremental decrease in peak flood water surface elevation or increases conveyance capacity as compared to existing conditions\(^5\). Actions selected for future consideration were grouped based primarily on implementation constraints.

- **Short Term Actions:** Actions that can be constructed in 5-10 year planning and implementation horizon. Multiple Bayland actions can be implemented in the short term. The most significant short term benefits can be realized in the Upper Baylands and adjoining low lands at or below 14 ft.

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\(^3\) Primary stakeholders in the NHS study included the City of Novato, North Marin Water District, Novato Sanitary District, the Bel Marin Keys Community Services District, the Ca. Coastal Conservancy, and interested public members.

\(^4\) Watershed conditions were characterized via flow monitoring, watershed and geomorphic field assessment, and calibrated numerical models developed for the project in Phase II.

\(^5\) The NHS utilized numerical models to evaluate and characterize the hydraulic benefit of each Alternative.
• **Medium Term Actions:** Actions that can be constructed in a 10-15 year planning and implementation horizon. Actions that require additional studies, landowner coordination and possibly acquisition or easements to implement. Addition of flood storage at Stafford Dam and on the upper Novato Creek floodplain yield significant flood reductions for City parcels. Lower Bayland levee realignments downstream of Highway 37 expand flood mitigation benefits downstream.

• **Long Term Actions:** Actions that can be constructed in a 20+ year planning and implementation horizon to support long term adaption to increasing storm magnitudes and sea level rise. Actions modify City storm drain and street infrastructure to increase City flood conveyance and storm water drainage along designated urban drainage corridors (floodways). Bayland coastal flood protection is shifted landward to upland boundaries to the extent feasible.

1.1.1 **Short Term Alternative:**
The Short Term Alternative consists of those actions that can be constructed in 5-10 year planning and implementation horizon. Figures ES-1 shows the location of the Short Term Alternative elements. A brief description of the elements and their estimated costs are presented in Table ES-1. Short term actions will required additional funding, study, modeling, design and environmental compliance before they can be constructed.

In this preliminary look at flood control options upstream Grant Ave, several Short Term actions considered upstream of Simmons Lane were eliminated because, although they increased flood conveyance as intended, they also increased flooding downstream. This occurs because Novato creeks flow at or above capacity during large storm events, so actions which reduce overbank flooding upstream convey more water downstream. Given the constraints posed by the limited available downstream capacity in the Novato Creek, Warner Creek and Rush Creek drainages, no Short Term measures were identified to mitigate for the impacts of added upstream inflows. As a result, at Q50, the short term alternatives have limited benefits upstream of Diablo Ave. (Figure ES-2). In this and all alternatives, flood reduction benefits are greater at lower flows, as illustrated by analysis of the 10-yr. storm event. However, more opportunity for flood mitigation exists in the undeveloped baylands. The Short Term Alternative makes use of MCDPW’s expansive diked bayland parcels to attenuate flood peaks one to three feet, and accelerate flood recession in the corridor (Figure ES-3). The result is a significant decrease in peak flood water surface elevations (1-3 ft), and an increase in sediment conveyance capacity through the dredge reach which can be expected to reduce the frequency of maintenance dredging. The increase in tidal prism in the upper bayland provides downstream benefit in a corresponding increase in the self-sustaining channel

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6 Attachment B provides a detailed description of elements.
geometry (width and depth) in the lower bayland. This is expected to reduce the frequency and extent of maintenance dredging required downstream of Hwy37.
Figure ES-1: Short Term Alternative Elements
Table ES-1: Novato Watershed Project: SHORT Term Alternative Summary

<table>
<thead>
<tr>
<th>Proposed Action</th>
<th>Preliminary Cost Estimate</th>
<th>Cost Range (Cost + Uncertainties)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Upper Novato Creek Storage and Floodplain Improvements</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>S-1 <strong>Restore Floodplain Upstream of Bowman Canyon (Leveroni Creek)</strong></td>
<td>$1,500,000</td>
<td>$2,000,000</td>
</tr>
<tr>
<td>to expand existing channel cross section on public parcels upstream and downstream of Bowman Canyon to increase the active flow area. Modify tributary outfalls to discharge across available floodplain. Protect/expand riparian corridor via floodplain excavation and grading.</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Lower Warner Creek Drainage Improvements</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>S-2 <strong>Install Storm Drain Flap Gates: Nave Gardens and Center Rd</strong></td>
<td>$150,000</td>
<td>$250,000</td>
</tr>
<tr>
<td>to reduce backflow from creeks to streets.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>S-3 <strong>Increase Arroyo Avichi Diversions to Lynwood Basin</strong></td>
<td>$1,500,000</td>
<td>$2,000,000</td>
</tr>
<tr>
<td>to decrease volume of water and sediment being directed into the aggregating Novato Creek confluence by modifying the diversions structure, removing coarse sediment and increasing culvert capacity at So. Novato Blvd.</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Scottsdale Marsh Conveyance/Storage Improvements</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>S-4 <strong>Increase Scottsdale Marsh Conveyance</strong></td>
<td>$4,000,000</td>
<td>$5,000,000</td>
</tr>
<tr>
<td>to improve drainage from low lying portions of So. Novato Blvd and Center Rd.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>install a pump in Scottsdale Pond to maintain discharges during large storm events.</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Novato Baylands (Downstream of Hwy 101)</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Novato Creek Dredge Reach:</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>S-5 <strong>Redesign Dredge Reach /Reduce Coarse Sediment Loading</strong></td>
<td>$2,800,000</td>
<td>$4,200,000</td>
</tr>
<tr>
<td>to reduce the excavation extent, volume and frequency while maintaining flood conveyance.</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Novato Creek Channel: Upper Bayland</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>S-6 <strong>Spillway and Storm Water Basin for high flow bypass to No. DIB</strong></td>
<td>$2,270,000</td>
<td>$2,800,000</td>
</tr>
<tr>
<td>to increase floodplain conveyance, attenuate peak flood WSEs and protect the NWPRR Bridge. Install culverts to provide gravity drainage of floodwaters from No. DIB back to Novato Creek during low tides.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>S-7 <strong>Remove Novato Creek South Levee (@Duckbill Pond and Heron’s Beak Pond)</strong></td>
<td>$3,240,000</td>
<td>$4,100,000</td>
</tr>
<tr>
<td>to increase the available flow area in an undredged reach. Removing the levees increases the available channel cross section by over 200%, improving flood and sediment conveyance and adding tidal prism to passively maintain a larger channel cross section.</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Novato Baylands: Lynwood Basin</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>S-8 <strong>Divide Lynwood Basin (70% storm water/30% tidal)</strong></td>
<td>$5,400,000</td>
<td>$6,800,000</td>
</tr>
<tr>
<td>To increases operational value, open a portion of the basin to tidal exchange, providing a sediment storage area and increasing tidal prism and downstream channel geometry. Add gated culverts to permit gravity drainage from the storm water basin during favorable tides.</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Novato Baylands: West Basin</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>S-9 <strong>Restore Tidal Floodplain to West Basin Oxbow</strong></td>
<td>$3,900,000</td>
<td>$4,900,000</td>
</tr>
<tr>
<td>to expand the available channel cross section, and increase bayland tidal exchange and the associated stable channel dimensions (reduces downstream dredging requirements).</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Preliminary Cost Total:</td>
<td>$24,800,000</td>
<td>$32,100,000</td>
</tr>
</tbody>
</table>

Note: Costs presented here and throughout the document are based on conceptual designs. Estimates reflect 2016 Bay Area construction costs (RSMeans, 2015) and costs for similar projects constructed in the bay area in the past 1-5 years. Costs are intended to support planning, and for comparison between element actions, and do not include escalations for inflation, overhead and profit.
Figure ES-2: Q50 Short Term Results for Novato Baylands
Figure ES-3: Q50 - Existing and Short Term Alternative Water Surface Elevation at MAX Flood
1.1.2 Medium Term Alternative:

Medium Term elements are those that can be implemented in a 10-15 year time frame. Figure ES-4 maps the elements which make up the Medium Term Alternative. A brief description of the elements and their estimated costs are presented in Tables ES-2. The greatest reduction in depth and extent of City flooding occur as a result of the concurrent increase of flood storage and floodplain attenuation upstream of Sutro Ave. In the tidal baylands, expanding the corridor at Hwy 37 and breaching the eastern portion of the lower Bayland further reduces flood peaks throughout the baylands, and accelerates flood recession in lower Novato Creek. Flooding around Pacheco Pond is limited via design of alternative discharge points to the BMK Restoration site. Medium term actions reduce the percentage of building flooded within the study area by 5%, and lower peak WSE 1-3 ft. throughout the Bayland corridor, effectively constrain flooding (Figures ES-5 and ES-6).

Table ES-2: Novato Watershed Project: MEDIUM Term Alternative Summary

<table>
<thead>
<tr>
<th>Category</th>
<th>Elements</th>
<th>Description</th>
<th>Preliminary Cost Estimate</th>
<th>Cost Range (Cost + Uncertainty)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Upper Creek Storage and Floodplain Improvements</td>
<td>M-1</td>
<td>Raise Stafford Dam (add 700 ac of Storage)</td>
<td>$10,000,000</td>
<td>$20,000,000</td>
</tr>
<tr>
<td></td>
<td>M-2</td>
<td>Modify Stafford Dam Tailwater</td>
<td>$2,000,000</td>
<td>$10,000,000</td>
</tr>
<tr>
<td></td>
<td>M-3</td>
<td>Restore Floodplain Downstream of Bowman Canyon (Bowman Creek)</td>
<td>$1,000,000</td>
<td>$1,500,000</td>
</tr>
<tr>
<td>Vineyard/ Warner Creek Drainage Improvements</td>
<td>M-4</td>
<td>Nave Gardens: Install Pump to Novato Creek</td>
<td>$2,500,000</td>
<td>$3,100,000</td>
</tr>
<tr>
<td>Scottsdale Marsh Conveyance/Storage Improvements</td>
<td>M-5</td>
<td>Expand Scottsdale Marsh Storage</td>
<td>$5,000,000</td>
<td>$10,000,000</td>
</tr>
<tr>
<td>Novato Baylands (Downstream of Hwy 101)</td>
<td>M-6</td>
<td>Expand Novato Cr. Channel (within available right of way)</td>
<td>$3,370,000</td>
<td>$4,200,000</td>
</tr>
<tr>
<td></td>
<td>M-7</td>
<td>Direct Pacheco Pond peak flood outflows to BMKV</td>
<td>$2,040,000</td>
<td>$2,500,000</td>
</tr>
<tr>
<td></td>
<td>M-8</td>
<td>Raise Perimeter Levees &amp; Add Outfalls to Increase Storage Capacity</td>
<td>$2,934,000</td>
<td>$3,700,000</td>
</tr>
<tr>
<td></td>
<td>M-9</td>
<td>Set Back NC North Levee to Split basin (Tidal Exchange and Storm water)</td>
<td>$3,650,000</td>
<td>$4,560,000</td>
</tr>
<tr>
<td></td>
<td>M-10</td>
<td>Raise Levees to Reduce Hwy37 Flooding</td>
<td>$1,010,000</td>
<td>$1,270,000</td>
</tr>
<tr>
<td></td>
<td>M-11</td>
<td>Breast and Retain Levees to Restore Muted Tidal Wetlands</td>
<td>$7,860,000</td>
<td>$9,820,000</td>
</tr>
<tr>
<td>Preliminary Cost Total</td>
<td></td>
<td></td>
<td>$41,400,000</td>
<td>$70,700,000</td>
</tr>
</tbody>
</table>
Figure ES-4: Medium Term Alternative Elements
Figure ES-5: Q50 Medium Term Results for Novato Creek
Figure ES-6: Q50 - Existing and Medium Term Alternative Water Surface Elevation at Max Flood
1.1.3 Long Term Alternative:
Long Term elements are those that can be implemented in a 20+ year time frame. Implementation of these actions support long term adaption to increasing storm magnitudes and sea level rise and including infrastructure relocation or modification. Figures ES-7 maps the elements which make the Long Term Alternative. A brief description of the elements and their estimated costs are presented in Tables ES-3. Long term actions in the Novato’s creek corridors expand medium term work in upper watershed floodplain restoration and in lower watershed storm drain and surface street improvements. City flooding is reduced primarily by engineering overland conveyance corridors to restrict floodplain inundation, and increase storm water drainage efficiency (Figure ES-8). Long term actions in the Bayland relocate much of the remaining flood control infrastructure to the upland perimeter, while maintaining coastal flood protection for Hwy 37 and the recently improved railroad ROW (Figure ES-9).

Table ES-3: Novato Watershed Project: LONG Term Alternative Summary

<table>
<thead>
<tr>
<th>Project</th>
<th>Preliminary Cost Estimate</th>
<th>Cost Range</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Novato Creek (Upstream of Hwy 101)</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Upper Creek Storage and Floodplain Improvements</td>
<td></td>
<td></td>
</tr>
<tr>
<td>L-1: Restore Ohair Park Floodplain</td>
<td>$1,120,000</td>
<td>$1,400,000</td>
</tr>
<tr>
<td></td>
<td>to expand existing channel cross section upstream and downstream of Bowman Canyon, modify triburary outfall to discharge across available floodplain. Protects expanded riparian corridor via floodplain excavation and grading.</td>
<td></td>
</tr>
<tr>
<td>Surface Streets/Storm Drain/Sanitary Lines</td>
<td></td>
<td></td>
</tr>
<tr>
<td>L-2: Street/Storm Drain/Sanitary Line Improvements (Novato Blvd.)</td>
<td>$3,000,000</td>
<td>$3,750,000</td>
</tr>
<tr>
<td></td>
<td>to constrain indirect overbank flood waters, reduce flooding impacts and accelerate flood recession. Modify community infrastructure along designated floodways. Routing flood water around the Novato Creek confluence maintains stormwater drainage during high tides.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Others locations may be added.</td>
<td></td>
</tr>
<tr>
<td><strong>Novato Baylands (Downstream of Hwy 101)</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Deer Island Basin North</td>
<td></td>
<td></td>
</tr>
<tr>
<td>L-3: Remove North Bank Levees to No/So. DIB Expanding Bayland Floodplain</td>
<td>$7,680,000</td>
<td>$9,600,000</td>
</tr>
<tr>
<td></td>
<td>to add flood conveyance and sediment storage capacity. Opening the entire basin to tidal exchange increases the self-sustaining channel geometry locally and downstream. The floodplain supports natural geomorphic development returning baylands and provides a deposition zone for creek sediments. Rapid degradation can be anticipated post construction. Grading/banking of coarse sediment may be required to maintain creek conveyance during wetland development.</td>
<td></td>
</tr>
<tr>
<td>Deer Island Basin South</td>
<td></td>
<td></td>
</tr>
<tr>
<td>L-4: Tidal Wetland Conversion to support NoDIB actions</td>
<td>$1,590,000</td>
<td>$1,990,000</td>
</tr>
<tr>
<td></td>
<td>Remove levees and construct channels to add contiguous wetland floodplain area upstream of Hwy 37. Actions protect SGD forces from scour, and may require relocation of access.</td>
<td></td>
</tr>
<tr>
<td>East Basin</td>
<td></td>
<td></td>
</tr>
<tr>
<td>L-5: Remove Flood Control Levees along the Novato Creek Left Bank</td>
<td>$3,760,000</td>
<td>$4,700,000</td>
</tr>
<tr>
<td></td>
<td>to reduce community infrastructure and increase operational efficiency. The added connectivity supports more natural geomorphic development and provides a contiguous delta region for channel migration and sediment deposition.</td>
<td></td>
</tr>
<tr>
<td>North Basin: No Actions</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Preliminary Cost Total</td>
<td>$17,200,000</td>
<td>$21,400,000</td>
</tr>
</tbody>
</table>
Figure ES-7: Long Term Alternative Elements
Figure ES-8: Q50 Long Term Results for Novato Creek
Figure ES-9: Q50 - Existing and LONG Term Alternative Water Surface Elevation at Max Flood
1.2 Alternatives Analysis

The NHS study utilizes numerical models to evaluate the efficacy of study alternatives based on the change in conditions from those predicted for existing conditions in the watershed. Changes in the extent of flooding are depicted on plan maps, and quantified based on the number of building impacted. In the largely undeveloped bayland, the analysis looks at the change in flood WSE maxima and changes in flooded area. Bayland analysis also evaluates the change in the water surface gradients during flooding and flood recession. These gradients drive the transport of water and sediment into and across the bayland. Flow velocity and shear stress profiles/maps were also evaluated as a measure of resulting change in sediment transport capacity or flood recession rate across the bayland.

In the Novato/Warner Creek drainages maximum flood WSEs are reduced along the creek corridors (due to upstream changes), and in low lying areas which accumulate overbank flows from upstream and/or benefit from WSE reductions created by bayland actions. The greatest benefits are observed at Q10⁷ flows, with lesser benefit found at Q50/Q10⁸. Per Table ES-4, at Q10, short term actions yielded a 13% reduction in building impacted, while medium and long term alternatives yielded a 40% reduction. At Q50 short term actions yield nominal benefits (flood impacts were reduced less than 1% across the valley floor) while medium and long term actions yield only a 6-8% reduction in buildings impacted for Q50 and Q100 flows respectively. Benefits for Q50 flows occurred primarily in Nave Gardens and downstream where both a pump and bayland reductions occur. Within these areas are critical City of Novato fire and hospital facilities. All Alternatives yielded small benefit at higher flows because they only partially alleviated flooding at Q10, and could provide minimal additional benefit for the added Q50/100 volumes. Given the limited peak flood water level reduction predicted upstream of Diablo Avenue, Chapter 6 recommends additional study and evaluation of modified and additional elements.

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7 Q10, Q50 and Q100 refer to design storms of increasing magnitude. The number references the probability of occurrence of a storm event of a given size in any given year. For example, a Q10 event, commonly referred to as a 10-year storm, has a one in ten probability or 10% chance of occurring in any given year. The 50-year (Q50) and 100-year (Q100) storms have a 2% and 1% probability of occurrence in any given year.

8 In general, Q50 and Q100 storms have a comparable peak flood WSE. Q100 storms have a greater duration and storm volume.
Table ES-4: Changes in Effected Buildings with Alternative

<table>
<thead>
<tr>
<th>Alternative</th>
<th>Buildings Effected by 6&quot; or Greater Flood Depth</th>
<th>Reduction in Number of Building Effected</th>
<th>% Reduction of Effected Buildings</th>
</tr>
</thead>
<tbody>
<tr>
<td>Existing Conditions(Q10)</td>
<td>419</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Short Term (Q10)</td>
<td>365</td>
<td>54</td>
<td>13%</td>
</tr>
<tr>
<td>Medium Term (Q10)</td>
<td>251</td>
<td>168</td>
<td>40%</td>
</tr>
<tr>
<td>Long Term(Q10)</td>
<td>253</td>
<td>166</td>
<td>40%</td>
</tr>
<tr>
<td>Existing Conditions(Q50)</td>
<td>1214</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Short Term (Q50)</td>
<td>1202</td>
<td>12</td>
<td>1%</td>
</tr>
<tr>
<td>Medium Term (Q50)</td>
<td>1154</td>
<td>60</td>
<td>5%</td>
</tr>
<tr>
<td>Long Term(Q50)</td>
<td>1112</td>
<td>102</td>
<td>8%</td>
</tr>
</tbody>
</table>

Fortunately, in stark contrast to the urbanized creek corridor, the large amount of capacity available in the Novato Baylands provides significantly more opportunity for flood mitigation. East of Hwy 101, maximum flood WSEs decrease with distance downstream under both existing and proposed conditions. When compared to current conditions, all alternatives reduce peak flood water surface elevations across the baylands, reduce the areal extent of flooding and increase bayward flow and sediment transport gradients from tidally influenced reaches as far upstream as Diablo Avenue.

Figure ES-10 presents the predicted Q50 peak flood WSE profiles from Diablo Ave, to San Pablo Bay. Short (red), Medium (blue) and Long (green) Term Alternatives reduce peak flood WSEs by 1-3 ft., with benefits attenuating with upstream and down from actions. Increases in Lower Novato and
Warner Creek drainage are supported by all bayland actions, which reduce peak flood WSEs at Diablo Ave. by approximately 0.5-1 ft. at all evaluated discharges. Within the baylands, all Alternatives create a stepped flood profile which reflects increased flow and sediment movement into restored basins, and a reduction in conveyance in the basins where flood waters slow across the expanded floodplain and sediment is deposited. Predicted velocities within the Novato baylands becomes less uniform with each alternative. Novato Creek channel velocities increase through the dredge reach and where the channel narrows. Concurrently, channel velocities rapidly decrease where flows enter newly created tidal basins. This hydraulic structure results in an increase in sediment conveyance toward the newly restored tidal basins, and sediment deposition within the basins. The rate and location of sedimentation will depend on frequency, magnitude and recurrence of storm events.

In Novato Baylands flooding begins in the corridor near Hwy 37, with upstream and then downstream areas flooding shortly thereafter. Figure ES-11 maps Q50 WSE peaks and the areal extent of flooding for existing conditions and study alternatives. Along the Novato Creek corridor, color shifts from warm to cool indicate decreasing flood stage. Basins newly open and flooding are depicted. Basin WSE maxima are not shown because flooding continues to expand across the bayland following flood peaks, and subsequent high tide periods. Of equal importance is the increase in the slope (color shift) within the Novato Creek channel between the creek confluence and the bayland, which indicates the strength of the bayward gradients in peak flood. In all design storms, the Alternatives increase this slope. In addition to attenuating peak flood WSE, expansion of the bayland tidal floodplain also reduces the tidal amplitude in non-flood conditions. This enhances the flood mitigation benefits by lowering the starting water surface elevation in basins, and increasing potential storage capacity in the tidal basins.

Short term actions lower flood stages both in the upper bayland and in the dredged confluence reach upstream. Restoring tidal wetlands at West Basin does not provide a comparable amount of flood relief upstream because the channel cross section is at a minimum at Hwy 37, and limits conveyance in in adjacent bayland reaches. Flooding is reduced on the adjacent BMK and private agricultural lands downstream. With the expansions of the Hwy 37 crossing and restoration of tidal wetlands in Deer Island and East Basins, Medium term elements create larger and more wide spread reductions in flood WSEs, and eliminate Q50 flooding along the Novato Creek corridor, at Hwy 37 and at BMK. Long term actions further expand wetland restoration and reduce Q50 and Q100 peak flood WSE to below the current FEMA base flood elevation (BFE) of 10 ft. NAVD88.

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9 Diablo Ave. is the approximately the limit of both current tidal influence and bayland actions benefit in the corridor.
Figure ES-11: Q50 Peak Flood Water Surface Elevations (Plan View)
1.3 General Flood Study Findings:

Presented below are general findings for the Novato Creek Hydraulic Study. These findings present both the improved understanding of watershed conditions, and the analysis of study alternatives.

1. The **1984 Novato Flood Control Project** maximized conveyance through the Novato Creek study area. Despite these actions, Novato and Warner Creeks are both near conveyance capacity at Q10 or greater discharges.
   - Ongoing floodplain development has further impacted (reduced) flood storage and infiltration on the valley floor increasing runoff to Novato’s creeks
   - Existing bridges pass flood waters and are not point sources of flooding
   - Channel area decreases downstream as discharge accumulates and generates overbank flooding
   - Novato and Warner Creeks conveyance downstream of Seventh St. is reduced during high tide events.
2. In Q10 storm events:
   - Flooding occurs on Novato and Warner Creeks within the City limits and in the Novato Baylands.
   - Novato Creek overtops its banks and produces flooding upstream of Simmons Lane and downstream of Seventh St. where accumulating inflows exceed channel capacity. Flooding along Novato Creek extends north toward Railroad Ave. which discharges to Rush Creek, and South toward Warner Creek. Flooding at both these locations results from both local high water in the creeks and the accumulation of floodwater from upstream watershed areas.
   - The valley floor dips south, conveying much of Novato Creek overbank flows upstream of Grant Ave. toward Warner Creek.
   - Warner Creek floods parcels north of the creek downstream of Seventh St., and south of the creek downstream of Diablo Ave., along both Center Rd. downstream of McClay Rd. and South Novato Blvd.
   - Novato baylands flooding starts at the narrowed Hwy 37 crossing and subsequently tops north and south levees at Pacheco Pond.

3. In larger storm events:
   - Flooding is concurrent on Novato and Warner Creeks, and there are no alternate routes with capacity.
   - Flooding along the narrows between Miwok and Pioneer Parks acts to reduce flood pressure downstream on Novato Creek.
   - This overbank water flows west/south from Novato Cr. to Warner Cr. and beyond, and increases flooding in Warner Creek drainages.
   - City storm drains exceed capacity and/or backwater creating localized flooding: upstream of Miwok Park; in the Rush Creek corridor: and in the lower Warner Creek drainage downstream of Seventh St along Center Rd. and So. Novato Blvd (Nave Gardens).

4. In a Q50 storm event:
   Creek flooding extends over much of the valley floor along both Warner and Novato Creeks. Flood depths are typically less than one foot. Flooded depths of 1-3 feet occur:
   - Adjacent to Vineyard Creek between Wilson Ave. and McClay Rd.;
   - Along Warner Creek from Grant Ave. to So. Novato Blvd;
   - Along Novato Blvd. upstream of Grant Ave.
   - Southeast of Diablo Ave. where high tides restrict drainage and accumulated water spreads north along Railroad Ave. and south along So. Novato Blvd. /Center Rd.
   - Downstream of Seventh St, Novato Creek flooding and backwater from adjacent storm drains collects to the north along Redwood Blvd., and then flows north toward Rush Creek. Storm drain and creek outfalls along the Rush Creek drainage also do not have
adequate storm capacity, and discharges to the north result in Rush Creek drainage flooding.

- Bayland flooding expands along the Hwy 37 corridor and at Pacheco Pond, inundating adjacent parcels. In addition, levees are overtopped adjacent Hwy 101, along the BMK Community North Lagoon, and at Lynwood and North Deer Island Basins.
- High water levels are sustained in throughout Novato Creek for more than 4 days following the 48-hr. storm event, reducing drainage capacity from storm drains and outfalls.

5. **In a Q100 storm event:**
   - Peak flood discharges are comparable to Q50 flood maxima, because Novato’s creeks overtop their banks at the same elevations. The Q100 storm duration and volume are greater than the Q50 storm, and results in deeper and more contiguous flooded areas encompassing much of Novato between Center Rd. and Grant Ave.
   - The greatest increase in creek flooding occurs along the Warner Creek corridor which receives both upstream tributary inflows and overbank Novato Creek water. When Novato Creek overtops its banks, flood waters flow south across Novato Blvd. and into the Warner Creek drainage both upstream of McClay Rd. and downstream of Seventh St/Tamalpais Ave.
   - Bayland flooding expands cutting off access to critical facilities, inundating NSD treatment facilities, obstructing Hwy 37, and inundating buildings around Pacheco Pond and at BMK.

6. **Peak Flood Water Surface Elevations (WSEs):**
   - Are comparable for Q50 and Q100 storm events because overbank flooding limits the maximum creek stage.
   - Rise at comparable rates in both Novato and Warner creeks
   - Decrease with distance downstream from Stafford Dam to San Pablo Bay
   - Decrease rapidly within the confluence reach where the valley floor transitions to bayland creating a strongly depositional environment.
   - Increase locally and create flooding at the Hwy 37/Railroad crossing due to narrowed levee alignments and an aggraded channel
   - Decrease rapidly with floodplain expansion and support natural deposition in Novato’s subsided bayland basins

7. **Sea Level Rise**
   - Can be expected to increase bayland water surface elevations 1-3 feet within the 50-year design horizon of the NHS study.
   - Will increase daily tide maxima to 8-10 ft.
o Downstream of Hwy 37, this increases both daily tide range and peak flood water surface elevation (WSEs). The daily tidal maxima will increase to near or above current Q50 flood maxima, and results in less than 2-3 ft of levee freeboard on most bayland levees.
  - Upstream of the Hwy 37 this increases does NOT increase peak flood WSEs because flood stages rise above tidal influence to 10-16 ft.

- Reduces City outflow capacity and increases sedimentation in the already aggrading Novato/Warner Cr. confluence reach between Diablo Ave. and Rowland Ave.
- Decreases bayland velocity maxima and slows flood recession in Novato/Warner Cr and across the baylands
- Is expected to continue, reaching 4.5 ft. by 2100 (BCDC, 2014), propagating impacts upstream, and requiring increasing dependence on storm water storage during high tides.

8. Levee Setbacks (Relocation of Bayland Leves to widen the creek corridors):
- Reduce peak flood WSEs by expanding the available conveyance area. These reductions will diminish over time due to sea level rise
- Increase the rate of flood attenuation and recession
- Increase bayward flow and sediment transport capacity during favorable tides
- Increase tidal prism (the volume of water exchanged daily by the tide) and in turn the size of the channel that is maintained without dredging during low flow conditions.
- Provide capacity for natural sedimentation and passive climate adaption via landscape response
- Improve the extent and ecological values of tidal wetlands and the Novato/Warner Creek corridors

9. Tributary Floodplain Restoration:
Benefits are limited in the extreme design storm events because elements do not retain a sufficient volume to provide downstream benefit
- At lower flow regimes, elements attenuate flooding, support ground water recharge in the riparian corridor ecotone, and reduces sediment loading to the creek
- Would require addition of main stem floodplain elements to increase floodplain storage, reduce downstream flow velocities and bed/bank erosion during large storm events.

10. Drainage Improvements in Lower Warner Creek Basin
- Increase the storm drainage volume by 30-50%, with adequate downstream storage.
- Significantly increase flood conveyance capacity and are not limited at high tide
- Do not decrease peak flood WSEs locally because of the added upstream inflows
- Increase the rate of overbank flood recession following large storm events
1.4 Alternative Analysis Conclusions

Short, Medium and Long Term Alternatives provide an incremental reduction on overbank flooding with each Alternative. Conclusion and recommendations for each alternative are presented below. This preliminary study evaluates Alternatives, groupings of elements, but does not quantify the benefits of individual elements. In general, Bayland actions yielded a larger reduction in peak flood WSE than creek actions. Additional dam storage and upper creek floodplain restoration appear to have the most significant benefits in non-tidal reaches. In the Baylands, levee setbacks and tidal wetland restoration yield significant benefit, which increases with the scale of action. Upper bayland actions yield benefits which impact both upstream reaches and down, and as such, have the greatest efficacy.

1.4.1 Short Term Elements:

The most effective short term elements are the ensemble actions in the upper baylands which expanded the available conveyance corridor (Element 3) and add tidal prism and sediment storage capacity (Element 7B). Implementation of the Short Term Alternative:

- Incrementally decrease but do not eliminate creek and bayland flooding
- Have the greatest benefit in Novato Creeks at Q10, and limited benefit at Q50 and Q100 when the creek flows significantly exceed capacity10.
- Increase flood recession rates and accelerate drainage from low lying areas
- Increase flood conveyance capacity on Warner Creek during high tides by routing water downstream via Scottsdale Marsh and Lynwood Basin
- Reduce bayland WSE maxima (1-3+ ft.) and the location and volume of flooding
- Limit Q10 bayland flooding to areas around Hwy 37
- Increase dredging efficiency without increased flooding
- Add valuable estuarine habit
- Yield benefits upstream of Hwy 37 due to added conveyance capacity in the creek corridor, which increases gradients from the dredge reach to the upper bayland, and adds storage capacity to potentially reduce the dredging frequency for aggrading sediment.
- Yield benefits downstream of Hwy 37 in that the Short Term alternative increases tidal prism upstream of Pacheco Pond by over 500 ac-ft., reducing the need for dredging in both the confluence reach, and in the Lower Baylands. Based on hydraulic geometry this is expected

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10 Peak flows recorded at the USGS Gauge at Novato Creek (Gauge 11459000) during the available period of record (1947 – 2015) exceed the 10-year recurrence interval a total of 6 times; the 5-year recurrence interval 2 times and; the 100-year recurrence interval 1 time. Recurrence estimates are from reported values provided in the FEMA FIS report 2014.
to yield an equilibrium channel width of > 200 feet (more than two times the existing channel width), and a 2-3 foot decrease in channel depth.

- Support sea level rise adaption by reducing daily tide range

### 1.4.2 Medium Term Elements:

The most effective medium term elements are the increase in Stafford Dam storage (Element M-1), excavation to increase conveyance at Hwy 37 (Element M-6), restoration of tidal exchange in half of No. Deer Island Basin (Element M-9) and East Basin (Element M-11).

Implementation of the Medium Term Alternative:

- Significantly, reduces flooding across the watershed when compared to short term elements
- Adding dam storage (700 ac-ft) and floodplain restoration in upstream reaches of Novato Creek provides the most significant reduction in the downstream flood volumes, allowing Novato Creeks to contain and convey a larger percentage of overbank waters.
- Incrementally reduce bayland peak flood WSEs by attenuating peak flood volumes and lowering the daily tide range, and in turn, pre-storm starting water levels across the bayland
- Increase drainage capacity and sediment conveyance rates from low lying creek and watershed areas
- In Novato baylands, contain and convey the 50 year storm events without overbank flooding
- Excavation of channel and marshplain at Hwy 37 removes a critical conveyance constriction at Hwy 37, increasing flow and sediment conveyance throughout the baylands
- Incorporate expansive East Basin levee and infrastructure setbacks in the lower Novato baylands which lower flood peaks downstream of Hwy 37, increasing conveyance throughout the bayland and downstream by expanding channel geometry at the Novato Creek/San Pablo Bay confluence.

### 1.4.3 Long Term Elements:

The most effective long term elements are the expansion of tidal exchange in No. Deer Island Basin (Element L-3), and the restoration of O’Hair Park Floodplain (Element L-1).

Implementation of the Long Term Alternative:

- Expand the work of medium term actions
- Improve flood conveyance and reduce flooding in both the Creek and Bayland corridors
- Work to reduce the impacts (extent and duration) of flooding in City streets by expanding undersized storm drains and establishing corridors which constrain and convey overbank flows
- Reduce peak flood WSE an addition 2 ft across the baylands
- Remove upland fill in bayland levees for beneficial reuse within the watershed
- Reduce the opportunity for future expansion of storm water storage capacity in North Deer Island basin (Additional consideration of the future needs for storm water storage is warranted prior to conversion of all of Deer Island Basin to tidal wetland.)
1.5 **Sea Level Rise Impacts**

Seal level rise analysis provided the most positive findings for the non-tidal reaches of Novato creeks (Figure ES-12). One to three feet of sea level rise did not impact peak flood water surface elevations in Novato/Warner Creeks upstream of Hwy 37. However, rising tides reduce creek flood recession rates and bayward sediment transport gradients during both typical and large storm events. SLR will increase sedimentation rates in the dredge reach and around low lying channels and outfalls, increasing the need mitigating bayland actions, and necessitating raising or increased maintenance for low lying outfalls.

Upstream of Hwy 37, in the 10-15 year design horizon, Short Term bayland actions provide mitigating measures for more than 1 foot of sea level rise. However, analysis of 3 foot SLR scenarios indicate that as sea level continues to rise, these improvements are not sufficient to mitigate the impacts of progressively rising tides. Downstream of Hwy 37, sea level rise increase peak flood WSEs, and with 3 ft SLR has an added adverse impact in that daily high tides rise to 9-10 ft. As normal tidal creek stages rise to within 2 ft of typical levee grades, the available freeboard for storm outflows decrease and overtopping risks rise. This rise in daily tide and storm peaks indicates that infrastructure improvements will be required to maintain existing levels of coastal flood protection. As a result, managed retreat is advisable to reduce long term maintenance costs for undeveloped basins east of Hwy 37.

1.6 **Recommendations**

1.6.1 *Priorities for Next Phases of Work*

- Upper bayland short term elements which maximize downstream flow and sediment conveyance and increase downstream sediment storage capacity
- Lower Warner drainage improvements to increase conveyance from So. Novato/Center Rd via Scottsdale Pond. Efforts should first meet capacity needs for Lower Warner Creek drainage before increasing Arroyo Avichi diversions.
- Beneficial reuse of dredged creek sediments and levee fill. This coarse sediment is a valuable resource and should retained and utilized for anticipated levee improvements and/or realignment
- Further evaluation of Medium Term elements which provided significant benefits and thereby may warrant reconsideration as short term actions:
  - Raise Stafford Dam and/or add storage upstream to reduce flood volumes
  - Expansion of Novato Creek at Hwy 37 to improve overall bayland flood and sediment conveyance

1.6.2 *Additional Projects:*

The following additional projects should be considered as part of short term work and funding requests
• Pacheco Pond water quality improvements – potential actions include
  o Improving circulation by modifying connector channel and/or inlet culverts
  o Increasing DO via aeration or reduction of nutrient loading
  o Excavation of organic rich sediment and decaying plant debris

• Coarse sediment management along Novato and Warner Creeks. Actions could include:
  o sediment removal from accessible aggrading bars
  o grade control structures to limit Warner Creek incision
  o Arroyo Avichi sediment removal upstream of the diversion to reduce confluence reach sedimentation locally and upstream
  o localized riparian floodplain restoration to reduce vegetation encroachment support channel storage

• City Storm Drainage Improvements to address capacity issues at:
  o Diablo Avenue discharging to Warner Creek
  o Grant Avenue outfall to Novato Creek
  o Sunset Parkway storm drains discharging to Lynwood Slough
  o North Railroad Ditch at Olive Avenue
  o San Marin/Mount Burdell inlets discharging to Novato Creek (sediment management)

1.6.3 Additional Study:
The follow concepts warrant additional study to reduce flood risks and impacts, improve sediment management and ecological conditions in the watershed:

• Evaluate Novato Creek main stem floodplain restoration, prioritizing work at and upstream of the Bowman Cr. confluence to:
  o Increase flood storage and reduce peak flood flows
  o Reduce peak flow velocities and downstream scour and sediment transport
  o Increase ground water recharge and ecological conditions in the riparian corridor

• Integrate Upper Creek floodplain restoration actions with raising Stafford Dam to mitigate Dam impacts, and maximize flood storage and peak flood attenuation upstream of Novato’s urban center

• Evaluate surface street/storm drain/sanitary line improvements along “floodways” to
  o reduce the impacts of extreme floods on property and infrastructure
  o increase flood recession rates and lessen the duration of storm impact
  o maintain access to critical facilities during storm events
- Evaluate additional options to increase flood storage and/or flow diversion upstream of Simmons La. Including:
  - Storage above Stafford Dam
  - Novato Creek floodplain enhancements upstream of Sutro Ave
  - Diversion of San Marin area drainages to Rush Creek Marsh
  - Local detention storage for tributary drainage areas

- Evaluate feasibility and costs benefit of realignment of lower bayland levees parallel to Hwy 37, to reduce the total length of levee required. Levee realignment and basin restoration would entail the loss of most of NSD summer irrigation disposal capacity, would result in a realignment of Novato Creek in the lower bayland, and could adversely impact navigable access from the BMKCSD to Novato Creek.