Corte Madera Creek
Flood Control Project

Summary Report of 2006 Unit 4 Design Alternatives

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1: Background and Technical Information

This summary report presents the analysis of several feasibility-level design alternatives for improving fish passage, bank stability, and flood flow capacity of Unit 4 of the Corte Madera Creek Flood Control Channel. Unit 4 is an approximately 2,750-ft long still natural section of Corte Madera Creek extending upstream from the existing Unit 3 concrete channel in Ross to Sir Francis Drake Blvd at the border between the towns of Ross and San Anselmo.

The options presented include a preliminary conceptual fish passage improvement design prepared by Michael Love & Associates (MLA 2006) and multiple feasibility-level bank stabilization flood flow capacity improvements for Unit 4, and associated hydraulic design recommendations for Lagunitas Road Bridge replacement, described in a technical memorandum prepared by Fluvial Geomorphology Consulting and Stetson Engineers (FGC and Stetson 2006).[1] The detailed technical memorandum was provided to the Marin County Flood Control and Water Conservation District and the Army Corps of Engineers (Corps) with the associated Hydrologic Engineering Center - River Analysis System (HEC-RAS) hydraulic model files for review by Corps technical staff, and incorporation into their environmental and public review procedures. A subsequent addendum was prepared to narrow recommendations after a meeting held on December 18, 2006 with the Technical Working Group of the Ross Valley Watershed Program (FCG 2006). After the addendum was published, on-going discussions about Unit 4 designs and the need to communicate those to a non-technical audience led to preparation of this summary report. It relies heavily on the earlier memoranda, but includes new information and is intended to be a stand-alone document. The National Fish and Wildlife Foundation funded the technical memoranda prepared by FGC and Stetson Engineers (2006) and by Michael Love and Associates (2006) under a contract awarded to Friends of Corte Madera Creek Watershed.

This report is intended for distribution to the public. It summarizes the technical memorandum by omitting the detailed descriptions of the modeling and discussions of a number of the alternatives that were omitted from consideration after modeling. This summary report also simplifies the nomenclature in the technical memorandum, which is based on that used by the Corps in its earlier studies. Some of the figures used in this summary report come from the technical memorandum but they have been renumbered.

1.1 Historical Background

The Corps completed the Corte Madera Creek Flood Control Channel Units 1-3 in approximately 1971. The existing approximately 4 ft-high timber bulkhead grade control structure and wooden Denil fish ladder were installed at the upstream terminus of the Unit 3 concrete channel at that time, pending planned improvements to Unit 4, located between Unit 3 and the boundary between Ross and Anselmo; however, planned continuation of the concrete channel was delayed by public opposition.

Since 1971, the Corps has conducted additional studies and prepared hydraulic and sediment transport models focused on evaluating the design performance of Units 1-3 following the 1982 flood, and prepared a

[1] FGC and Stetson (2006) and FGC (2006) can be downloaded at in the Library section at www.rossvalleywatershed.org/. MLA (2006) is contained in its entirety as Appendix A in FGC and Stetson (2006).

suite of seven design alternatives documented in 1999-2000 screening documents and hydrology and hydraulics appendix documents (Alternatives I-VIIB). None of these received strong public support. Concerns regarding some of the alternatives that provided the increases in capacity included aesthetic and environmental impacts of constructing a proposed concrete-lined sedimentation basin in the channel and removing a large percentage of the existing canopy-forming riparian trees to install new, up to 16 ft-high vertical steel sheetpile retaining walls along the east bank of Corte Madera Creek. There has also been a concern about the flood constricting effect of Lagunitas Road Bridge. Moreover, many of the Corps' larger capacity design alternatives were confounded by important concerns about flood flows leaving the channel upstream in San Anselmo and passing through Ross and into Kentfield on the residential floodplain rather than flowing in the to-be-improved Unit 4 channel and about the inability of Units 1-3 to accommodate local drainage at high flows.

1.2 Recent Project Developments and Technical Analyses

There have been a number of important developments and technical analyses since the 1999-2000 alternatives were presented, making it appropriate and timely to prepare and review new alternatives. First, the December 31, 2005 (2006 Water Year) flood renewed public interest in finding watershed-wide solutions to flooding in the Ross Valley. Using funds provided by the Coastal Conservancy, Marin County Department of Public Works Flood Control District has contracted with Stetson Engineers Inc. to prepare a new hydraulic model of the Ross Valley, including downtown San Anselmo, and to use the model to present to the public potential watershed-wide flood management improvements. These improvements will include an evaluation of the potential for reducing the frequency and amount of overbank flooding originating in downtown San Anselmo, and thereby keeping more flood flow in the Corte Madera Creek channel passing through Unit 4 rather than on the floodplain in Ross and into Kentfield.

Second, the Town of Ross has declared that it plans to remove and replace Lagunitas Road Bridge with a new presumably less constrictive crossing structure. Third, hydraulic analysis of the 1982 flood and expert peer review of the Corps' proposed sedimentation basin raised serious concerns about the effectiveness and necessity of the basin as part of Unit 4 flood control improvements.

Fourth, the existing wooden Denil fish ladder partially failed during the December 31, 2005 flood and a conceptual permanent fish ladder replacement design was recently completed by Michael Love and Associates, with funding provided to Friends of Corte Madera Creek Watershed by the National Fish and Wildlife Foundation.

Fifth, the Marin County Flood Control District, Zone 9 collected detailed survey topography in the Units 3 and 4 reach beginning at the upstream end of tidal influence in Unit 3 concrete channel and extending upstream to the Ross gage behind the Ross Fire Department engine house. The County revised these data in Spring 2006 in the vicinity of the new riprap bank stabilization structure on the east bank just upstream from the Unit 3 concrete channel (21 Sir Francis Drake Blvd).

Sixth, the Corps contracted with Treadwell-Rollo to prepare an updated, more comprehensive geotechnical analysis than had been available at the time the 1999-2000 alternatives were presented.

1.3 Pending Analyses

Work is currently underway by Stetson Engineers assisted by David Dawdy, Consulting Hydrologist, to update the stage-discharge rating curve for the Ross Gage using new field stage-discharge data collected by Stetson Engineers Inc. and Environmental Data Solutions in 2005-2006. The updated rating curve will allow the consultant team to convert stage data the County collected from 1996 to the present to annual peak discharge data, and thereby revise the Ross gage flood frequency analysis using the longer peak-flow record. Completion of these hydrologic analyses will allow more accurate recurrence intervals to be associated with the new design capacities of the five new options. In addition, Stetson Engineers currently is preparing calibrated steady and unsteady flow HEC-RAS models for identifying and designing conceptual fixes for the primary flood constrictions along the Corte Madera Creek mainstem from the estuary to the Lansdale Avenue culvert in San Anselmo, including constrictions in the Unit 4 reach. Among other things, these more comprehensive 2007 models will quantify the amounts of out-of-channel flow that originate in San Anselmo and bypass the Unit 4 reach, and verify or improve Unit 4 flood capacity estimates made by the new 2006 modeling summarized in this summary report.

1.4 Scope of New 2006 Modeling

The new 2006 model design alternatives are intended to reduce overbank flood flows passing into downtown Ross from the west bank of Corte Madera Creek along an approximately 800-900 ft-long study reach extending from the upstream end of the existing Unit 3 concrete channel to a location upstream from the private residence at 1 Sylvan Lane. Accordingly, the new design alternatives include channel modifications for fish passage, bank stabilization, and flood management improvement in this reach only. The new modeling work does not include channel modifications in Units 1-3.

The Corps' 1999-2000 design alternatives included channel widening, floodwall parapet design, and channel dredging in Units 1-3. These design elements have been carried forward unchanged in the 2006 options, with the exception that if the decision is made to leave the current capacity of Unit 4 (~3200cfs [cubic feet per second])[2] unchanged, the preliminary concept design replacement fish ladder structure would be located within the upstream end of the existing Unit 3 concrete channel. Michael Love & Associates proposed this location for the replacement permanent-type fish ladder to minimize potential impacts to the existing sanitary sewer siphon running beneath the creek about 20-25 ft upstream from Unit 3.

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[2] All existing conditions and proposed design channel capacities reported in cubic feet per second (cfs) are estimates determined by detailed hydraulic modeling. None of the model estimates of existing conditions channel capacity have been calibrated and verified because there are no reliable surveyed high water mark records for recent actual floods, the updated rating curve for the Ross gage has not been finalized so as to attach accurate discharges to individual actual recent floods, and problems with determining how much and where flood flow escapes and returns to the channel. Preliminary updated rating curve and model calibration information recently presented to the Ross Valley Watershed Initiative TWG by Stetson Engineers indicates good overall physical verification of the reported existing conditions channel capacities. Model estimated design conditions channel capacities cannot be physically verified because they have not been constructed. In general, it is important to note that while none of the model-estimated channel capacities is absolutely correct, the relative differences between capacities estimated by the model are valid. Also note that while none of the model-calculated floodwater surface elevations (in vertical ft) at any given location is absolutely correct, the differences in model-calculated floodwater surface elevation between existing and various design conditions are valid.

Again, only the downstream portion of the designated Unit 4 reach, up to the Ross gage, is modeled in detail by the 2006 design option. Flood management improvements in Units 1-3 and the upstream portion of Unit 4 may be addressed by the ongoing Ross Valley Watershed modeling effort.

1.5 Assumptions Made for the New 2006 Modeling

To provide internal consistency with other components of the Corte Madera Creek Flood Control Project and the hydraulic modeling underway in the watershed, the following assumptions were made for this work:

1. **Existing Model:** The HEC-RAS project files supplied by the U.S. Army Corps of Engineers for the four 1999-2000 design alternatives (3,200 Existing Conditions Plan; 4,100 cfs Minimal Plan; 5,400 cfs Plan with 5-yr dredging cycle; and 5,400 cfs plan with 10-yr dredging cycle) other physical constraints and definitions were used, with modifications as noted in items 2, 3, and 4 below. These parameters are described in the full Technical Memorandum (FGC and Stetson 2006).

2. **Updated Topographic Survey Data:** In 2005, topography was resurveyed from the upstream extent of tidal influence in the concrete channel to the vicinity of the Ross flow gage. For the 2006 modeling, this file was updated to include changes to topography immediately upstream of the concrete channel that occurred during the December 31, 2005 flood. The 1999 model geometry file data are used to represent Unit 1, Unit 2, the tidally influenced areas of Unit 3, and Unit 4 upstream from the gage location.[3]

3. **Lagunitas Road Bridge:** The 2006 model files include planned removal and replacement of Lagunitas Road Bridge with a structure that has no more hydraulic effect on the design capacity flow than the existing Lagunitas Road Bridge vertical concrete abutments.

4. **Sediment Basin:** The new model files do not include a concrete-lined sediment basin in the vicinity of the bridge and assume that the channel bed elevation in the bridge vicinity will be consistent with the undredged condition.[4]

5. **Protection of Sewer Lines:** The Ross Valley Sanitary District No. 1 (RVSD) maintains two parallel 24-inch diameter reinforced concrete pipe siphon sewer lines passing beneath the bed of Corte Madera Creek on a diagonal path immediately upstream from the existing wooden Denil fish ladder. Design alternatives assume that any channel bed regrading, bank regrading, and/or installation of vertical retaining walls along the west bank in the vicinity of the sewer line must provide for a minimum 2.5-ft deep riprap lining above the top of the existing concrete encasement surrounding the two 24-inch diameter sewer pipes. The east bank is heavily armored under existing conditions and is unlikely to be modified by the design alternatives given the negligible hydraulic effect of the armor materials in that vicinity. It is possible, however, that the existing vertical timber retaining wing

[3] Recent new post-dredging survey bathymetry data in the Unit 1 earthen channel will be incorporated in the larger hydraulic model analysis currently undertaken by Stetson Engineers. Channel geometry changes in Unit 1 do not affect model calculations in Unit 4 because there is an intervening section of supercritical flow in the Unit 3 concrete channel.

[4] Modeling the undredged condition produces a conservative result based on field observations that the dredged channel bed elevations do not persevere through an entire wet season. There may be minor flood capacity benefits of continued annual channel bed dredging particularly for lower to moderate floods occurring early in the wet season.

wall and riprap armor would be replaced as a maintenance measure during the construction of Unit 4 improvements, possibly using partially biotechnical stabilization techniques.

6. **Allowable East Bank Modifications:** Eight separate parcels comprise the east bank of the Unit 4 downstream from the Ross gage. The most upstream property is the Town of Ross municipal property, where it is assumed that the channel banks may be regraded if it can be demonstrated that the regrading would create a flood benefit. Further, regrading to maximum 1.5(H):1(V) finished slope would be preferable on the Town property as it would allow biotechnical stabilization and vegetation establishment and thereby have fewer aesthetic and environmental impacts. The second property is also a municipal property within the Lagunitas Road Bridge right-of-way where it is assumed that the bridge removal and replacement project planned by the Town allows an opportunity to move the replacement bridge abutments farther to the west if it creates a substantial flood benefit. Similarly, it is assumed that the Marin Art and Garden property encompassing approximately a 100-ft long section of the east bank immediately downstream from Lagunitas Road Bridge may be regraded if necessary to produce a substantial additional flood benefit, as would be balanced by the desire to preserve native ash trees at mid-bank and top-of-bank and the overall natural aesthetic characteristics immediately downstream from the bridge.

   The remaining five properties forming the east bank in lower Unit 4 are residential, three of which have existing permanent channel bank stabilization structures. It is assumed that no channel bank regrading would be acceptable to the landowners along the east bank, particularly if existing top-of-bank property area or trees would be removed by the grading work. It is assumed that the two properties without existing permanent stabilization structures should be individually analyzed by subsequent modeling during the detailed design phase to determine if minimum impact biotechnical bank stabilization measures could be constructed at the sites in a manner that would improve long-term bank stability and provide a demonstrable flood benefit, while also not substantially reducing existing top-of-bank area.

   It is also assumed that any of the design alternatives that include channel bed regrading and/or removal of the existing timber bulkhead grade control and wooden Denil fish ladder structure will provide protection against channel bed downcutting that may destabilize any of the existing natural channel banks or permanent bank stabilization structures on the east bank.

   There was general public opposition to the Corps' 1999-2000 5,400 cfs design alternative, for one because of the perceived aesthetic and environmental impacts of its up to 16-ft high vertical steel sheetpile retaining wall to be located along the east bank downstream from the bridge. Both to reduce the aesthetic impacts of a new retaining wall in this alignment, and to avoid potentially unnecessary modifications to private property, the new modeling work assumes that high design capacity alternatives that would require a new vertical wall to sufficiently increase channel width in constricted sections locate the new wall on Town property along the opposite (west) bank, where it would be less visible from the pedestrian right-of-way and parking area near the Post Office.

7. **Allowable West Bank Modifications:** Four separate properties form the west bank along the lower Unit 4 reach downstream from the Ross gage. The most upstream is a residential property directly across Corte Madera Creek from the Ross gage. It is assumed that bank regrading within this

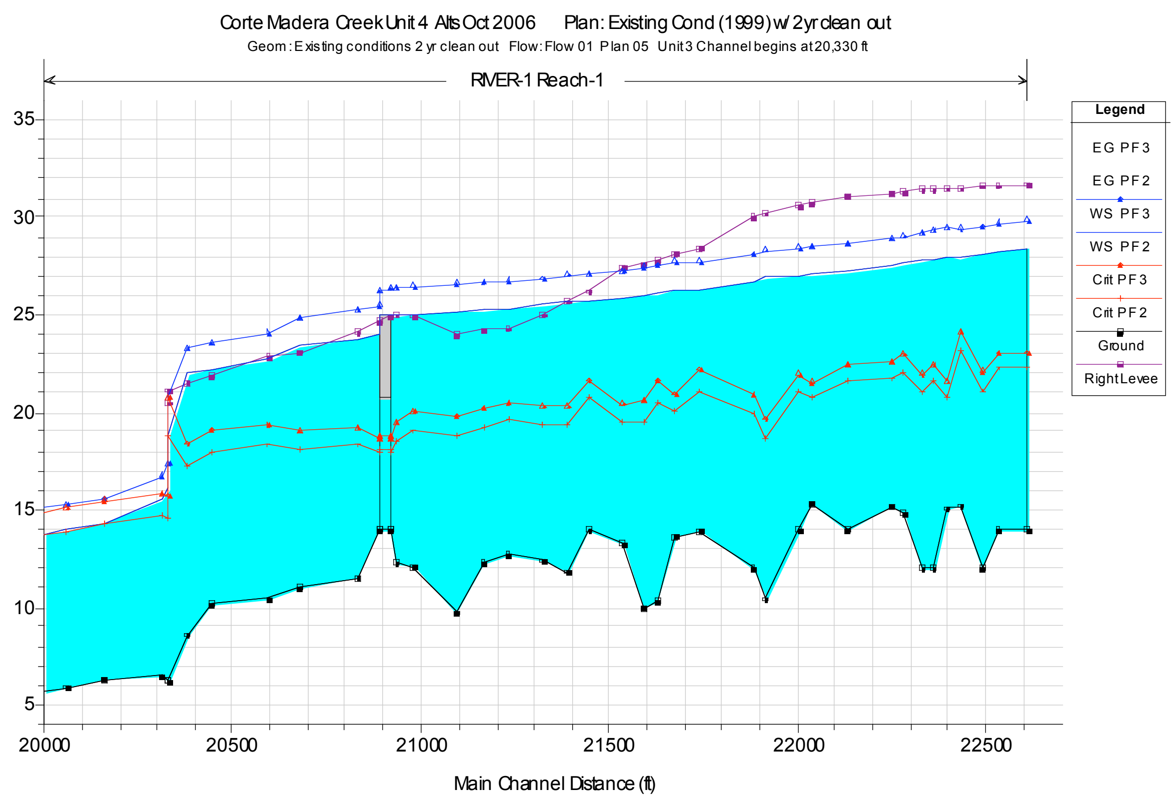
property may not be acceptable, nor would it likely create a substantial flood benefit due to the apparent flood flow constriction created by the existing encroached private residential vertical steel sheetpile retaining wall immediately downstream at 1 Sylvan Lane. It is further assumed that the existing retaining wall at 1 Sylvan Lane cannot be removed or modified. (Recall from item 6 above that necessary channel widening in the vicinity of the 1 Sylvan Lane retaining wall would be more feasible by regrading and biotechnically stabilizing the opposite east bank.) However, it is assumed that moving the west bank Lagunitas Road Bridge abutment and wingwalls farther out as part of the bridge replacement design would be acceptable to the Town if it is part of a preferred, presumably relatively high-capacity design alternative. The west bank downstream from the bridge is Town of Ross property containing numerous mature native riparian canopy-forming trees at low-, mid-, and upper bank locations, and a pedestrian right-of-way and power and water utilities at the top of the bank. The new modeling work assumes that a range of design alternatives should be developed to simulate regrading the west bank both minimally, preserving the majority of existing native riparian trees, and severely, demonstrating the maximum feasible design capacity of the channel.

8. **Definition of Unit 4 Channel Capacity:** In developing the 1999-2000 design alternatives, the Corps specifically defined Unit 4 channel capacity as the maximum discharge that does not overtop the bank at a single location, the 25 ft bridge deck elevation at the upstream face of the Lagunitas Road Bridge. This was an appropriate definition for then-existing conditions because the bridge is a major hydraulic constraint and was considered a constant feature that would not be changed. Relatively minor amounts of overbank flow upstream and downstream from the bridge occurring when the bridge deck is just overtopped, as shown in Figure 1, could be mitigated by relatively inexpensive and low-impact measures where the west bank dips below the elevation of the bridge deck, including raising the finished top of pavement elevation on Sylvan Lane or constructing a low floodwall bordering the lane, and placing temporary seasonal sandbag levees along the existing chain link fence downstream from the bridge. Figure 1 shows the top-of-bank elevation profile incorporated in the new model files; it is clear that the west bank elevation profile is neither uniformly sloped nor parallel to floodwater surface elevation profiles.

   The 2006 design alternatives attempt to apply a comprehensive reach-scale definition of channel capacity that is functionally equivalent to the single-location 1999-2000 Corps definition. Reach-scale channel capacity considers the difference between model-calculated floodwater surface elevation profile and the top-of-bank elevation profile everywhere along the study reach. The Unit 4 design channel capacity is therefore limited by excessive overbank flow occurring at any single location along the west bank from the Ross flow gage location downstream to the Unit 3 concrete channel. Therefore, either or both the lowest portion of the top-of-bank elevation profile, or the highest local portion of the floodwater surface elevation profile could cause consistent overtopping by a lower discharge than the rest of the study reach, i.e. be the "weakest link" in the system.

   And, consistent with the 1999-2000 Corps definition, some limited amount of overtopping along the study reach is allowed within the reach-scale definition of channel capacity. Unit 4 channel capacity is defined in this summary report as the maximum discharge that produces a model-calculated water surface elevation profile that is nowhere 1.0 ft higher than the above-defined west top-of-bank elevation profile downstream from the Lagunitas Road Bridge location, and not greater than 25.0 ft at the Lagunitas Road Bridge location. Water surface elevations slightly greater than the bank are allowed immediately upstream from Lagunitas Road Bridge where the Sylvan Lane elevation dips down. It is thought that these maximum depths of overbank flow could be mitigated by an appropriately designed replacement Lagunitas Road Bridge and with relatively inexpensive and unobtrusive temporary seasonal or permanent low floodwalls placed along individual sections of the west top-of-bank.

Figure 1: Comparison of estimated water surface profiles for 3,250 cfs (PF2) and 4,100 cfs (PF3) in the Unit 4 reach for 1999 existing conditions geometry (g04)



Note: Flow direction is right to left. Modeled water surface overtops the right bank (Right Levee) downstream of the bridge in two locations. In both locations the modeled water surface elevation exceeds the elevation of the bank by less than one foot.

Source: FCG and Stetson 2006

2: Components of 2006 Designs

At least three primary flood-flow constraints in Unit 4 downstream of the Ross gage need to be addressed through the various design options. They are:

1. Unsmooth transition between Unit 4 and Unit 3, created by the existing timber bulkhead grade control structure and the wooden Denil fish ladder immediately upstream from the Unit 3 concrete channel, and the relatively narrow channel cross-sections 20, 50, and 130 ft upstream of the fish ladder.

2. Narrow channel constriction created by the existing east bank vertical concrete retaining wall at 27 Sir Francis Drake Blvd.

3. Narrow channel constriction created by the existing west bank vertical sheetpile retaining wall at 1 Sylvan Lane.

The technical memorandum (FGC and Stetson 2006) describes the results of modeling more than 20 alternatives developed to identify effective components that are both feasible and contribute to meeting the project goals of improving fish passage, bank stability, and flood flow capacity. These are grouped into four categories, discussed separately in this section. The specific recommended options discussed in Sections 3 and 4, were developed by combining the design components described below and then modeled using HEC-RAS. Other options that use different combinations of the components or that use modifications of the components could be developed, but they have not been modeled. The components listed below are shown in plan view on Figure 2.

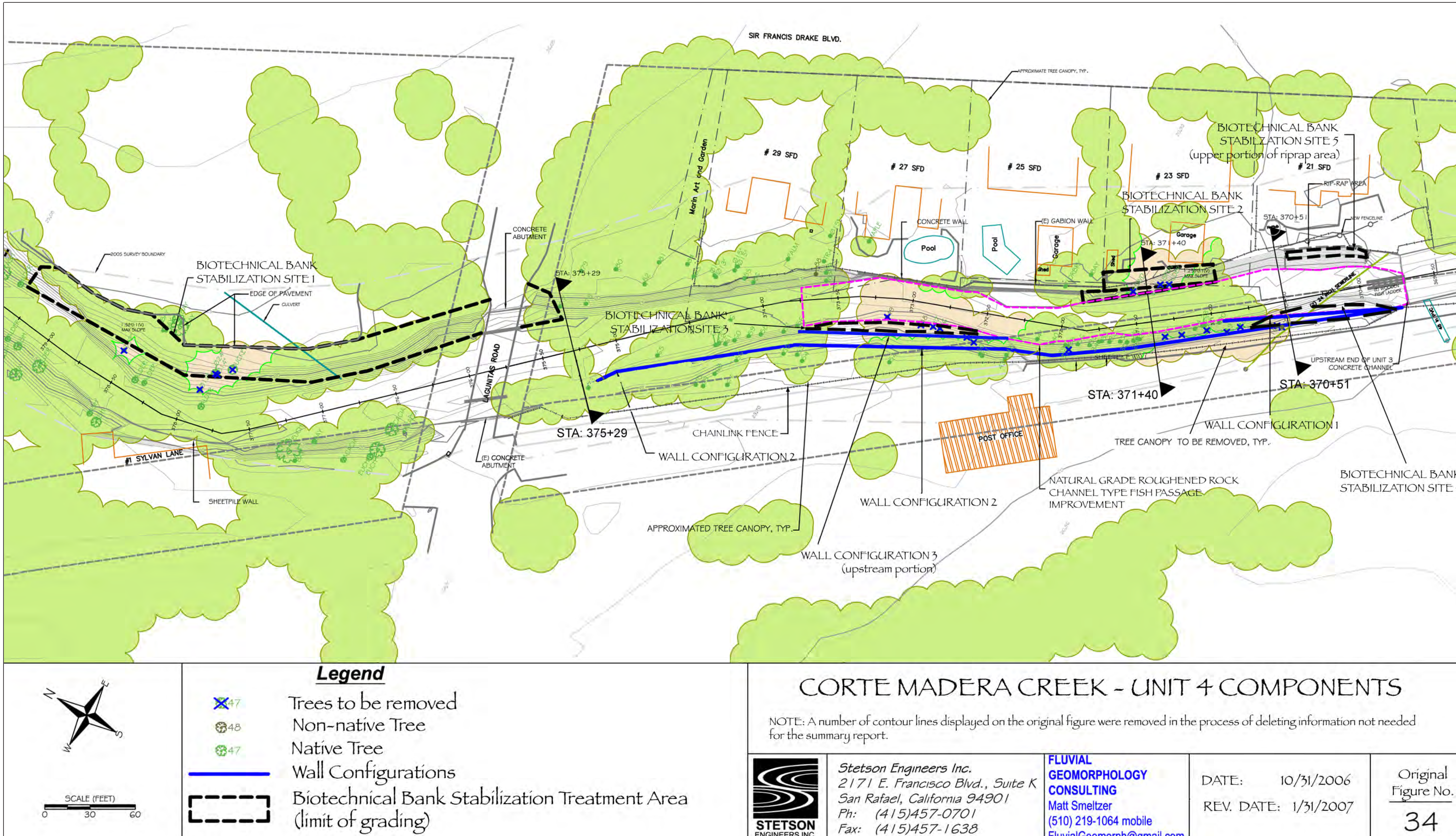
2.1 Removal of Fish Ladder

The wooden fish ladder and bulkhead at the upstream end of the concrete channel is a significant constriction. Simply removing the existing grade control fish ladder structure and locally redistributing some of the existing riprap (not including any channel widening, tree removal, or bank regrading in the Unit 4 reach) would reduce the water surface elevation at 4,100 cfs approximately 6 vertical ft at the entrance to Unit 3, decreasing uniformly to an approximately 1.5 vertical ft reduction at the Lagunitas Road Bridge location, then to about 0.2 ft at the Ross Creek tributary confluence. This action would increase Unit 4 flood capacity from approximately 3,200 cfs for the present condition to approximately 5,100 cfs. However, this action alone would provide no protection against downcutting upstream of the concrete channel, which could jeopardize the sewer lines and retaining walls on the east bank.

2.2 Roughened Rock Channel

If the fish ladder and bulkhead are removed, there is some concern that downcutting of the stream bed could occur, potentially compromising fish passage, exposing the sewer buried in the creek bed, and undermining retaining walls along the east bank. Installing a mildly sloped roughened rock channel immediately upstream of the concrete channel would avoid these potential problems. This way, grade control and fish passage can be provided without a replacement permanent concrete fish ladder structure.

Figure 2: Plan view of project components



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General Characteristics of Roughened Rock Channels: A roughened channel or "nature-like" fishway is an oversteepened channel designed to allow for passage of fish and other aquatic organisms in addition to accommodating peak flows and associated debris and sediment. The primary hydraulic function of a roughened channel is to create conditions suitable for fish passage while dissipating energy through an oversteepened section of channel. Hydraulic criteria for fish passage in a roughened channel include maximum water velocities, minimum water depths, and maximum turbulence.

The bed of a roughened rock channel is constructed with an engineered mixture of sediment ranging from very large angular rock to natural rounded river gravel and finer sediment. By careful arrangement of the protruding large angular rocks, the steep sections of a roughened channel form rock cascades, which increase the channel's overall roughness to dissipate energy and improve fish passage. These cascades form complex flow patterns with large variations in water velocities, providing migrating fish numerous pathways to choose from as they swim upstream. Smaller rock and finer material fills voids in the mixture and prevents seepage of low flows into the bed. To maintain stability, the maximum recommended slopes for roughened channels range between 4 and 5 percent. A gentler slope may be required to avoid excessive turbulence or the need for extremely large rock to maintain stability.

Unit 4 Roughened Rock Channel: A 400-ft long, 0.7 percent[5] slope "natural grade" type roughened rock channel is recommended to provide grade control from the entrance to Unit 3 to the upstream end of the existing vertical concrete retaining wall at 27 Sir Francis Drake Blvd. A reinforced concrete below-grade "cut-off" wall would also be required to protect the upstream cross-section of the Unit 3 concrete channel. The cross-section profile of the roughened rock channel would be designed for fish passage at low flows, with the large angular rock forming boulder weirs that would promote a suitable, focused water width and depth at fish migration flows. Although flood flows would be expected to deposit native sediment and natural gravel bars on a portion of the completed channel bed, the arrangement of boulder weirs would maintain suitable low-flow depths for fish passage through the 400-ft long channel.

2.3 Biotechnical Bank Stabilization

The Unit 4 design analysis includes an emphasis on using biotechnical bank stabilization techniques to stabilize design-modified channel banks to the extent feasible. Biotechnical or bioengineered bank stabilization structures are generally defined as those that maximize use of live native vegetation, live logs and woody debris, natural soil, and biodegradable fabric materials, and minimize use of traditional engineering bank stabilization materials such as rock riprap, and vertical concrete and steel retaining walls. Feasibility of biotechnical techniques is generally limited where existing or design bank slopes exceed approximately 45 degrees or 1(H):1(V). Because most of the channel banks in Unit 4 approach or exceed 1(H):1(V) slope under existing conditions, biotechnical techniques will not be feasible everywhere. Biotechnical techniques will have limited application in the higher channel capacity design options, because increasing the channel capacity requires widening the bed of the channel and making the channel banks steeper than existing. Still, all of the design options include the maximum feasible amount of biotechnical treatments, and for aesthetic reasons, only biotechnical techniques would be applied on the east bank where they will be more visible from public areas including the pedestrian right-of-way.

[5] Note that the natural slope of Corte Madera Creek is approximately 0.2-0.3 percent in the study reach.

Within the lower reach of Unit 4, three locations are appropriate for widening the channel using biotechnical bank stabilization.[6] Two of these are located along the east bank where existing west bank structures and utilities prevent achieving necessary minimum channel widths with additional west bank grading. The third is located on the west bank in a narrow reach where the existing west bank slope is approximately 2(H):1(V) and could theoretically be reduced to 1.5(H):1(V) using biotechnical stabilization. Two locations on both banks immediately upstream from the Unit 3 concrete channel are also appropriate for biotechnical bank stabilization, but primarily for riparian vegetation enhancement and accommodating a natural grade type roughened rock channel, and secondarily for their minor impact on flood capacity.

Site 1: The first east bank biotechnical site is on Town of Ross property across the creek from the existing vertical steel sheetpile wall at 1 Sylvan Lane, which encroaches into the stream. The proposed east bank regrading work would be centered on the narrowest cross-section directly across the creek from the sheetpile wall, and would extend upstream about 130 ft and extend downstream about 218 ft to the existing upstream face of the Lagunitas Road Bridge location (Figure 1). The toe of the bank would be graded back to achieve a 40-ft minimum channel width along the entire 348-ft long site. The bank would be graded back to maximum 1.5(H):1(V) slope extending up to the existing edge of pavement on the Town property. The finished slope would then be hydroseeded, planted with native trees and shrubs, and drip-irrigated for 2-3 years. Existing alders near the toe of the existing bank would be preserved, but at least 5 native riparian trees would be removed from the mid-bank area to accommodate necessary channel capacity.

Site 2: The second east bank biotechnical site is on private residential property at 23 Sir Francis Drake Blvd across from the existing vertical steel sheetpile wall at the back of the Ross Post Office. The site is situated between an existing rock-filled gabion mattress-wall structure at 25 Sir Francis Drake Blvd, and an existing approximately 1(H):1(V) sloped riprap covered bank at 21 Sir Francis Drake Blvd. The upstream approximately 68-ft long portion of the site would be graded back to maximum 1.25(H):1(V) slope to meet a minimum 28-ft channel width without necessarily destabilizing the existing garage foundation at the proposed top-of-bank design.[7] The finished slope would be hydroseeded, covered with biodegradable geofabric, and vegetated with native riparian canopy forming trees (e.g., native willow and alder on the lower slope and native ash, maple, and oak on the upper slope), and drip-irrigated for 2-3 years until trees are established. The bank section immediately below the existing garage foundation may also require lining with vegetated riprap. The entire graded area would be protected with 18- to 24-inch minimum diameter riprap placed along the toe of the existing bank to extend the hydraulic profile of the existing gabion basket mattress at 25 Sir Francis Drake Blvd. The approximately 68-ft long toe protection would be constructed to form a bench at the same elevation as the existing alders rooted across the channel from the site, with sufficient void spaces on the top of the bench and near the toe of the fabric and rock covered upper bank to allow backfill with sand-and-gravel and planting 1-gallon native alders. Three existing native trees on the mid-bank would be removed.

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6 Note that biotechnical bank stabilization structures such as irrigated live willow brush layering and container plantings may also be appropriate for modifying the upper horizon of the existing new riprap bank protection structure at 21 Sir Francis Drake Blvd. to establish additional California native riparian canopy forming trees in the study reach and enhance aesthetics.

7 The 28-ft minimum channel width is for Options 3 and 5. Option 4 provides a 36-ft minimum width at the garage cross-section. It would incrementally increase the Unit 4 flood capacity under all design options if the owner of 23 Sir Francis Drake Blvd would be willing to allow the top of the bank to be moved 4-5 ft farther (total of 9 horizontal ft) to the east in the vicinity of the existing garage building in order to allow for a 40-ft minimum width under Option 4 and a 32-ft minimum channel width under Options 3 and 5.

Site 3: The existing west bank slope is 2(H):1(V) in the narrow reach constricted by the existing east bank retaining wall at 27 Sir Francis Drake Blvd. It is feasible to widen the bed of the channel along the length of the constriction from about 20-21 ft wide to about 28-29 ft wide by regrading the west bank to maximum 1.5(H):1(V) slope. This finished hydroseeded slope could then be stabilized using biodegradable geofabric and drip-irrigated plantings. It would also be feasible within this canopy-limited site to over-excavate the bank and install a live willow brush layering structure to create at the finished 1.5(H):1(V) slope. The biotechnical and retaining wall treatments would have the same impacts to existing riparian canopy-forming trees at the site.

Site 4: The existing west bank slope in the constricted channel section within 100 ft upstream of the Unit 3 concrete channel varies from approximately 1.5(H):1(V) to 1(H):1(V) or steeper. There is a considerable amount of light riprap lining the toe of the bank. For options that do not include a west bank retaining wall extending upstream from the Unit 3 concrete channel, it may be feasible to install oversteepened biotechnical stabilization along Site 4 to both accommodate the minimum roughened rock channel width and enhance the limited existing riparian vegetation at the site.

Site 5: The new approximately 12-ft high, 1(H):1(V) sloped riprap bank protection structure a 21 Sir Francis Drake Blvd was installed as an emergency measure immediately following the December 31, 2005 flood. It would be feasible to replace the existing riprap only in the upper 8-10 vertical ft of the bank with a similarly sloped biotechnical stabilization structure such as a drip- or spray-irrigated live willow brush layering combined with drip-irrigated riparian tree container plantings near the top of the bank to restore the riparian canopy.

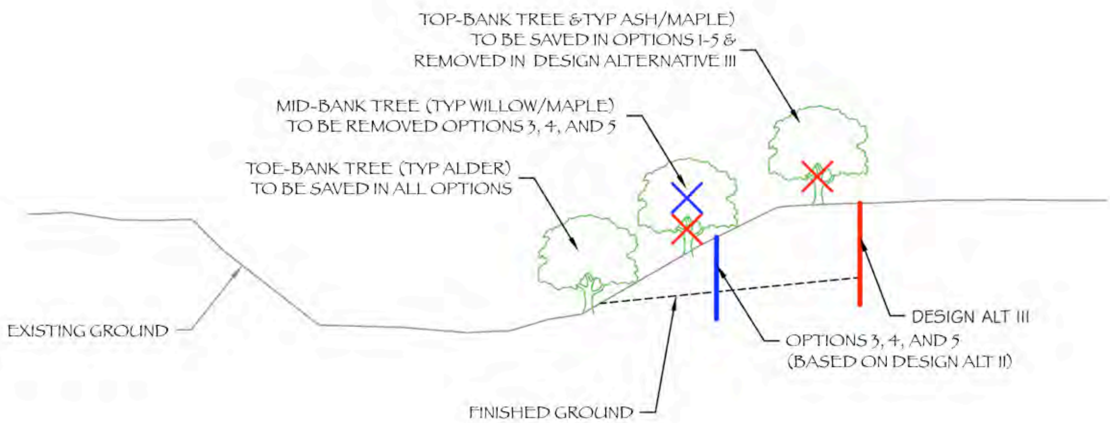
Detailed hydraulic modeling shows that biotechnical stabilization at east bank Sites 1 and 2 reduce floodwater surface elevations in the study reach, but the stabilization at west bank Sites 3 and 4 have a negligible effect on flooding; vertical retaining walls are necessary to create 32-ft and wider minimum channel widths. Replacement of riprap with biotechnical stabilization at Site 5 would have a negligible effect on flooding.

2.4 Vertical Walls

Because requiring only biotechnical stabilization measures would somewhat constrain the maximum flood capacities, higher capacity design options that include numerous vertical wall configurations were modeled in combination with removal of the fish ladder, installation of the roughened rock channel, and biotechnical bank stabilization described above.

Figure 3 presents schematic cross-sections that illustrate the relative impact of mid-bank and upper-bank vertical retaining walls on existing riparian vegetation. Mid-bank walls allow trees at the toe of the bank and those at the top-of-bank to stay in place, essentially preserving the overall aesthetic and functional characteristics of the existing riparian canopy. An upper-bank wall that reaches the top of the bank would require removal of mid-bank and top-of-bank trees, although trees at the toe would stay. It should be noted that there are reaches where some or all of these areas do not have trees, so each specific wall configuration must be evaluated separately for its impact on riparian vegetation.

Figure 3: Conceptual cross-section



Source: FGC and Stetson 2006

Wall Configuration 1: An approximately 114-ft long maximum 9-ft high vertical retaining wall at mid-bank along the west bank beginning immediately upstream of Unit 3 would widen the locally 20-ft wide channel to be the same as the 32-ft width of the Unit 3 concrete channel. This wall, when included in a plan with removal of the fish ladder, installation of the roughened rock channel, and biotechnical bank stabilization at three sites, negligibly reduces the water surface elevation an additional approximately 0.5 ft in portions of the study reach, but has a negligible effect on overall design channel capacity.

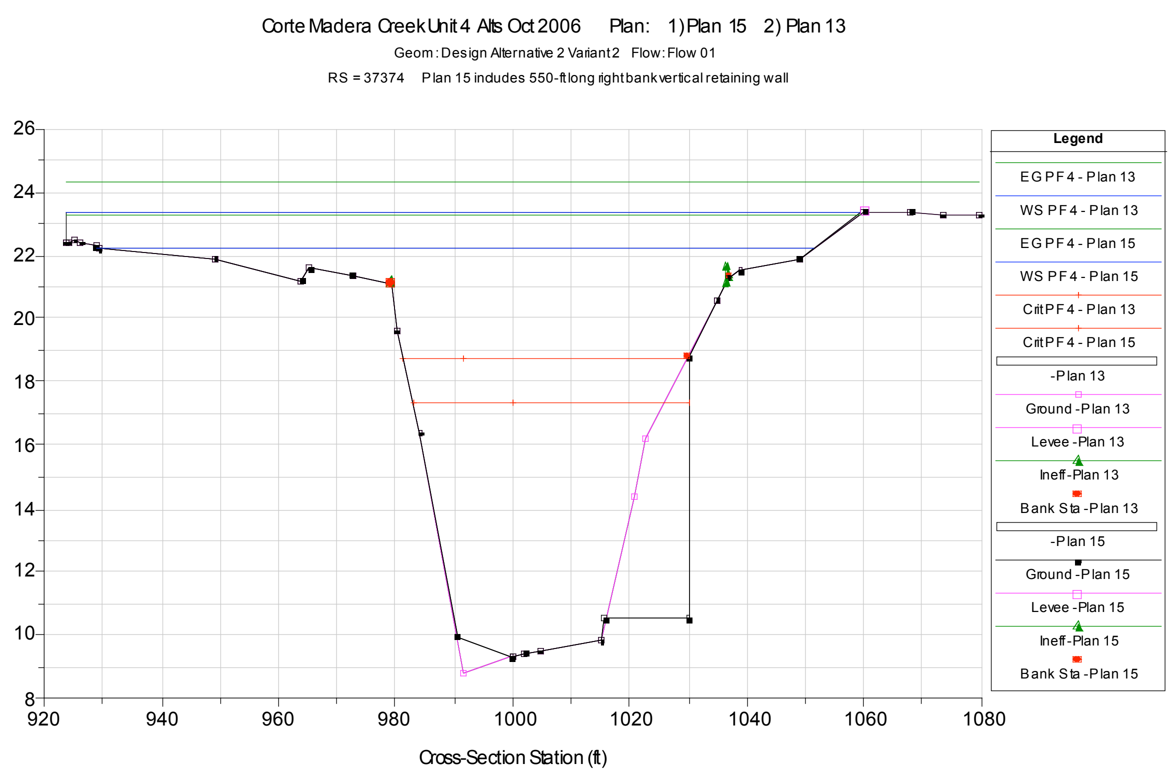
Virtually all of the existing native riparian canopy-forming vegetation in the proposed grading area (native willow) was recently removed during emergency construction access to construct the east bank riprap bank at 21 Sir Francis Drake Blvd immediately following the December 31, 2005 flood. The grading activities for installing Wall Configuration 1 would therefore have negligible impacts on the existing riparian corridor. The upper bank area above the 114-ft long retaining wall could be covered with biodegradable geofabric and planted and drip-irrigated to establish new native canopy forming trees. Wall Configuration 1 would likely only be visible from the east bank residential properties.

Wall Configuration 2: This approximately 550-ft long mid-bank vertical concrete or steel sheetpile retaining wall would widen the Unit 4 channel to meet a 40-ft minimum channel width most of the distance between the Unit 3 channel and the existing concrete wingwall downstream of the Lagunitas Road Bridge. An exception would be the 36-ft minimum width at the 23 Sir Francis Drake Blvd garage cross-section; (see footnote 7). By careful design of the retaining wall alignment, Configuration 2 preserves the majority of existing native riparian canopy forming trees in the Unit 4 reach, and the overall character of the corridor and the aesthetic backdrop it creates for public space on the Ross Town commons. Figure 2 shows the plan for the proposed retaining wall, and the trees to be removed under this configuration, and the resulting reduction in the canopy cover.

First, widening the channel by installing the vertical wall some distance away from the existing toe of the channel bank allows the existing native alders to be saved and not removed. It is important to note that the existing alders are rooted at or within 1-2 vertical feet from the low-flow water surface, at the same elevation as natural free-forming gravel bars. Therefore, removing the alder and grading the channel bed down would produce a negligible additional flood management benefit – the gravel bars will simply reform at their former, pre-excavated, elevation during the first water year. It follows that preserving existing alders does not constrain maximum achievable design channel capacity. Furthermore, the existing alders have few horizontal branches and are rooted in lines parallel to the direction of flood flow, minimizing their hydraulic effect.

Second, the 550-ft long vertical retaining wall alignment was designed to substantially achieve the flood management objective while avoiding removal of the largest native riparian canopy forming trees near the top of the bank (primarily maple and ash). By saving the native alders along the toe of the bank and the maple and ash near the top of the bank, the majority of the canopy is preserved and the overall aesthetic character of the corridor would be substantially the same. Figure 3 shows, in concept, how placing walls along the mid-bank would save the toe-of-bank and top-of-bank trees, but necessarily remove the mid-bank trees. This way, the majority of the canopy cover is retained, as shown in Figure 2. Figure 4 shows an example cross-section profile at River Station 373+74 ft[8], located approximately 400 feet upstream from the fish ladder, where an

Figure 4: Comparison cross-section profiles for existing conditions (magenta) and for Option 2 (black) at the upstream end of the roughened rock channel, 404 ft upstream from Unit 3

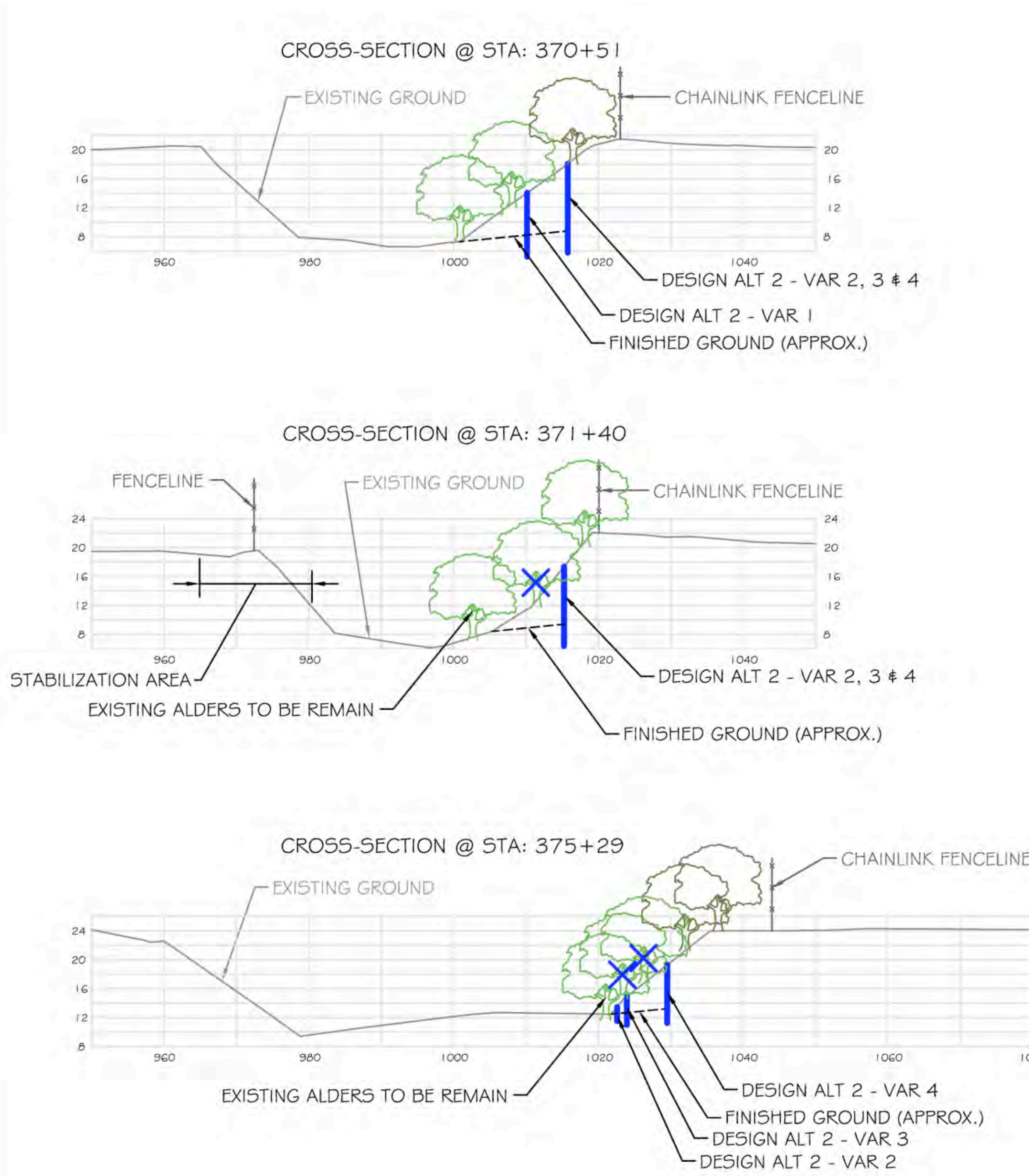


Source: FCG and Stetson 2006

8 River stations are shown on Figure 2, with the cross-sections at 370+21 ft, 371+40 ft, and 373+74 ft clearly marked.

existing alder is preserved at the toe of the bank, and two existing ash are preserved near the top of the bank. Figure 5 shows, in concept, the grading effects at other cross sections in the study reach.

Figure 5: Cross-sections showing wall configurations at three locations in the study reach



Source: FCG and Stetson 2006

Wall Configuration 2 would be largely invisible from the pedestrian right-of-way and parking area near the post office. The upstream end of the wall would likely be visible from the existing and future replacement Lagunitas Road Bridge and the east bank municipal and Marin Art and Garden property on the downstream side of Lagunitas Road.

Wall Configuration 2, when included in a plan with removal of the fish ladder, installation of the roughened rock channel, and biotechnical bank stabilization at two east bank sites, increases the design channel capacity from an estimated 5,100 cfs to an estimated 5,400 cfs, and reduces the capacity floodwater surface elevation to 24.5 ft at the Lagunitas Road Bridge location.

Wall Configuration 3: Wall Configuration 3 is a "hybrid" of Configurations 1 and 2 that includes two separate wall sections: the same 114-ft long wall as Wall Configuration 1 and a 160-ft long wall section that is a modified version of the central part of Wall Configuration 2. Wall Configuration 3 would meet a 32-ft minimum width in the two narrowest sections of Unit 4: (1) in the Unit 4/Unit 3 transition immediately upstream from the Unit 3 concrete channel; and (2) where the channel is constricted by the existing east bank vertical concrete retaining wall at 27 Sir Francis Drake Blvd. Like Wall Configuration 1, Wall Configuration 3 would meet only a 28-ft minimum width at the 23 Sir Francis Drake Blvd garage cross-section (see footnote 7). Like Wall Configurations 1 and 2, Wall Configuration 3 would avoid significant impacts to the existing riparian canopy and the overall aesthetic character of the corridor. The canopy impacts would be virtually the same as for Wall Configuration 2 (Figure 1).

Wall Configuration 3, when included in a plan with removal of the fish ladder, installation of the roughened rock channel, and biotechnical bank stabilization at two east bank sites would increase the Unit 4 flood capacity by approximately 300 cfs from an estimated 5,100 cfs to an estimated 5,400 cfs. Although the design flood capacity is the same as for Wall Configuration 2, the floodwater surface elevation is typically up to 0.5 ft higher than for Wall Configuration 2 along most of the study reach, including at the Lagunitas Road Bridge location.

Other Wall Configurations: Several wall configurations including minor variations to those above and several with much longer and higher walls located along the top of the bank were modeled. They are not described in this summary report because the improvements to capacity and/or water surface elevation were minor and the loss of native riparian trees was much greater than the three wall configurations described above.

3: Evaluating the Options Developed in the 2006 Modeling

The modeling provides two different ways to look at how flood flows would move through the reach. One is the volume of water conveyed and the water surface elevation. Comparing the water surface elevation to the top-of-bank elevation is crucial in evaluating the effectiveness of an option to reduce flooding. This section presents model results for existing conditions and for five specific options, including a graphic representation of the capacity water surface elevation each would produce in the study reach. All of these options assume that the Lagunitas Road Bridge has been replaced by a structure that does not affect capacity or water surface elevations in the lower portion of Unit 4.

3.1 How to Interpret Water Surface Elevation Charts

The estimated water surface elevation charts calculated using the HEC-RAS model are used to display and explain incremental model results. These charts (presented in figures 1, 6 - 9, and 11 - 13) compare model-calculated water surface elevations along the lower Unit 4 reach with estimated west top-of-bank elevation profile to show where and how much various discharges would overtop the west bank and begin to flow into downtown Ross and Kentfield. While the complete model extends from the downstream limit of the Unit 1 flood control channel at 16,640 ft main channel distance upstream to near the Ross Creek tributary confluence at 22,600 ft main channel distance, the charts only display the upstream 2,600-ft length of the model domain (the lower 2,280-ft length of Unit 4). The west top-of-bank profile is shown in the charts as the “Right Levee” or “West Top of Bank” line (purple). Consistent with the definition of Unit 4 channel capacity discussed in Section 1.5, upstream from Lagunitas Road the top-of-bank profile is taken as the elevation profile along Sylvan Lane. Downstream from Lagunitas Road it is taken as the elevation profile along the sidewalk pedestrian right of way.

The minimum channel bed elevation profile is shown in the charts as “Ground” or “Min Ch Bed” line (black). These are profiles depicting the minimum elevation from each of the model cross-sections. For charts that compare model results for two plans, both ground profiles are shown (black and magenta) for comparing model geometry. The model-calculated water surface elevation profiles (WS PF) are shown in blue, and the critical water surface elevation profiles (Crit PF) are shown in red. Where the associated model discharge is not contained in the chart legend, the model discharge is according to the profile number denoted and specified in the chart legend or title. The chart header displays the geometry title, plan(s), and flow file(s).[9] NGVD29 refers to the National Geodetic Vertical Datum of 1929, an approximation of mean sea level elevation.

3.2 Summary Comparison of October 2006 Design Options

The 2006 design options include one baseline (existing conditions) option and five design options, described below. The baseline option is not acceptable because it would retain the existing wooden Denil fish ladder that is a barrier to salmonid passage. Option 1 (no action) would improve fish passage by installing a state-of-the-art concrete pool-and-chute fish ladder within the upstream 68-ft length of the existing Unit 3 concrete channel. Although Option 1 would improve fish passage at a relatively low cost, it is not acceptable because it

[9] Table 1 in FGC and Stetson (2006) shows the Unit 4 discharges according to each profile (PF) number and flow file.

does not improve flood capacity of Unit 4 compared to existing conditions. Both the baseline alternative and Option 1 provide approximately 3,200 cfs flood capacity in Unit 4 (Table 1).

Table 1: Summary of option characteristics

Option	**New Fish Ladder**	**Remove Fish Ladder and Bulkhead**	**Roughened Rock Channel**	**Biotechnical Bank Stabilization at Site 1**	**Biotechnical Bank Stabilization at Site 2**	**Biotechnical Bank Stabilization at Site 3**	**Biotechnical Bank Stabilization at Site 4**	**Biotechnical Bank Stabilization at Site 5**	**Wall Config. 1 (mid-bank, 114 ft long)**	**Wall Config. 2 (mid-bank, 550 ft long)**	**Hybrid Wall Config. 3 (mid-bank, 114 and 160 ft long)**	**Modeled Capacity (cfs)**
Existing Condition												~3,200
Option 1	X	X										~3,200
Option 2		X	X	X	X	X	X	X				~5,100
Option 3		X	X	X	X	X		X	X			~5,100
Option 4		X	X	X	X			X		X		~5,400
Option 5		X	X	X	X			X			X	~5,400

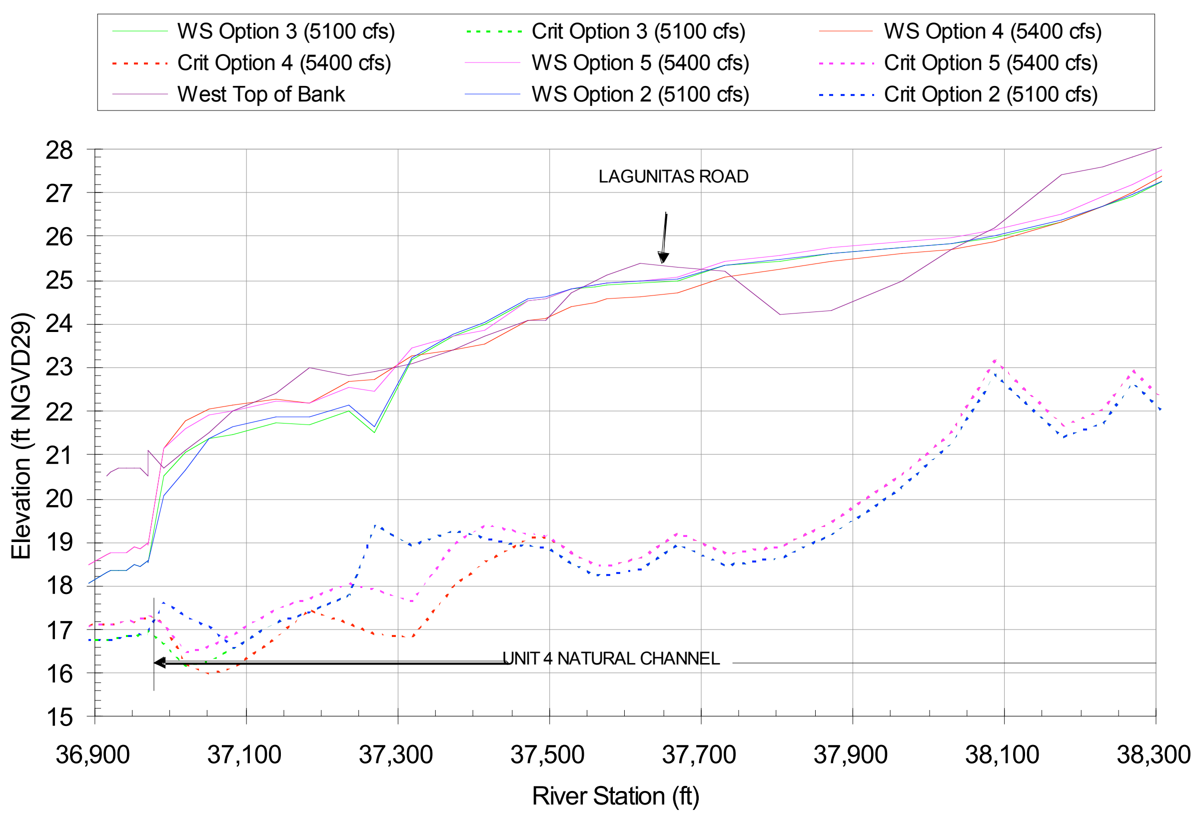
Option 2 was developed by considering a sequence of actions. Simply removing the bulkhead and wooden fish ladder and redistributing the existing large riprap in the channel bed area immediately upstream can increase the Unit 4 flood capacity from an estimated 3,200 cfs to an estimated 5,100 cfs. However, this is not acceptable because it would leave the streambed vulnerable to potential downcutting, and it would not provide adequate fish passage. Removing the existing wooden ladder and adding a natural grade type roughened rock channel to create a smooth hydraulic transition between the still natural Unit 4 channel bed and the existing concrete Unit 3 channel would protect against downcutting and improve fish passage conditions. Adding the roughened rock channel would have a neutral effect on flood capacity—the Unit 4 floodwater surface profile would be identical and the flood capacity would be the same, about 5,100 cfs. Installing the 400-ft long roughened rock channel sediment mixture per a to-be-determined detailed design would require extensive grading and construction work within the existing channel bed, but would require no channel bank regrading and minimal stabilization along the toe of the bank.

Option 2 would include removal of the fish ladder, installation of the roughened rock channel, and bank regrading and biotechnical bank stabilization at all five feasible sites (see Section 2.3). Including the biotechnical stabilization work at the five feasible sites would reduce the floodwater surface elevation about 0.5 ft along most of the study reach (Figure 6), but would not increase the flood capacity to more than 5,100 cfs (Table 1).

Options 3-5 would also protect against downcutting and improve fish passage with the same natural grade type roughened rock channel as Option 2, but would also increase the Unit 4 flood capacity by substantially modifying channel banks to widen the narrowest channel sections. Widening the channel enough to measurably increase flood capacity above 5,100 cfs requires vertical retaining wall section(s) in places along the west bank, and gradually sloped, vegetated (i.e., "bioengineered" or "biotechnical") bank stabilization treatments at two east bank sites. Options 3-5 include the same biotechnical bank stabilization at the two east bank sites, but different west bank wall configurations: Option 3 includes Wall Configuration 1; Option 4 includes Wall Configuration 2; and Option 5 includes Wall Configuration 3 (Table 1).

Because the three wall configurations widen the channel at the Unit 4 flood constrictions by different amounts, each would produce a slightly different floodwater surface elevation profile and a different pattern of shallow overbank flooding during the design capacity flood (Figure 6).

Figure 6: Estimated flood capacity water surface profile comparisons for Options 2, 3, 4, and 5.



Repeated hydraulic modeling shows that 5,400 cfs appears to be the maximum flood capacity the Unit 4 natural channel can convey without adding permanent low floodwalls that rise above the top of the bank. Both recent detailed hydraulic modeling documented in the October 31, 2006 memorandum, and previous detailed modeling documented in the 1999 and 2000 Army Corps of Engineers memoranda have shown that 5,400 cfs is the practical maximum design flood capacity for Unit 4.

The 5,100 cfs and 5,400 cfs design options have arguably negligible differences in the design flood capacity; their differences are more in environmental, aesthetic, and overall project cost objectives and criteria. Most customizations of any of the options would yield a design flood capacity in the same range. The largest difference between the floodwater surface elevation profiles occurs at and upstream from the Lagunitas Road Bridge location, and may affect bridge replacement design flexibility.

4: Existing Condition and Selected Options

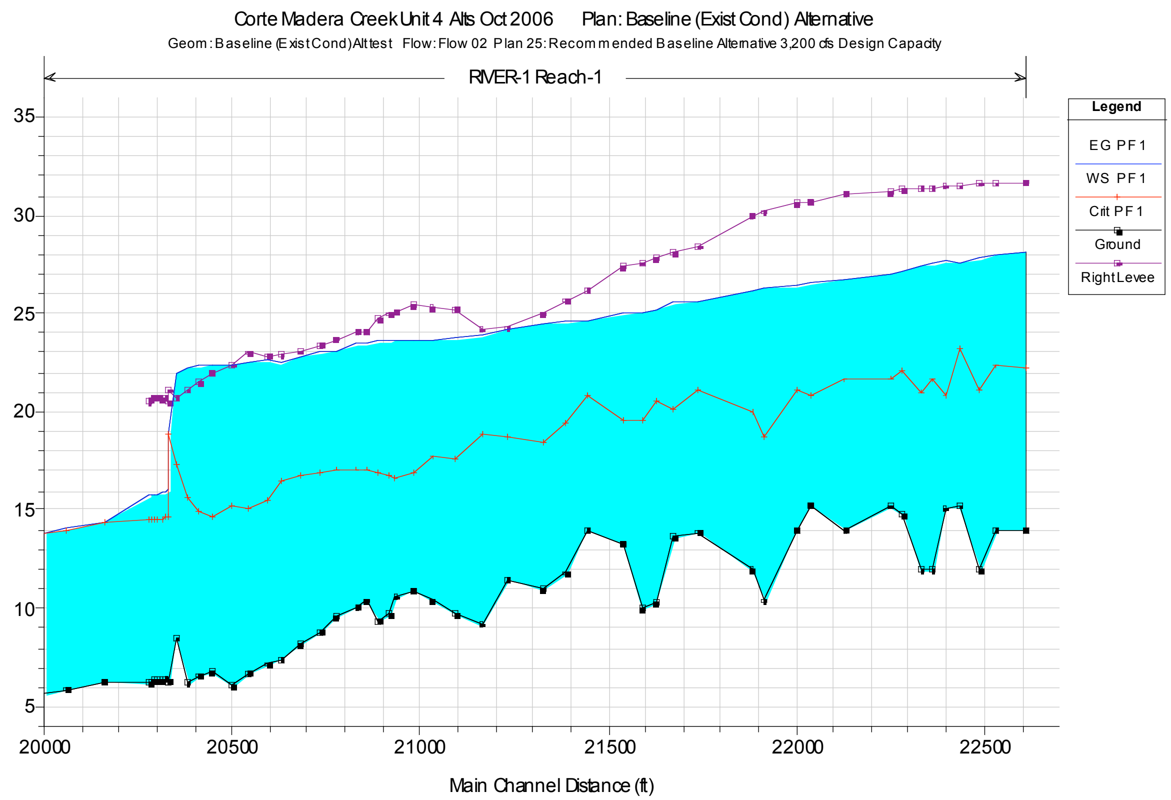
This section presents a group of options (see Table 1) recommended for analysis in the public environmental review process required by state and federal laws. We include a description of the existing condition for comparison and an alternative that does not increase capacity, but which would treat the barrier to salmonid passage at the fish ladder. The designs are intended to address multiple objectives, including:

- fish passage improvement in the Unit 3/4 transition;
- increased flood flow capacity;
- preservation and restoration of native riparian canopy forming trees;
- preservation of the natural aesthetic character of the stream;
- grade control maintenance and bank stability;
- existing sanitary sewer line protection; and,
- hydraulic design for Lagunitas Road Bridge replacement.

4.1 Existing Condition without Lagunitas Road Bridge

To provide a basis for comparison with the various options, the existing condition without the Lagunitas Road Bridge was modeled.[10] The estimated design capacity for the existing condition is 3,200 cfs, which produces a maximum 1.1 ft overbank flow at the west bank immediately upstream from the Unit 3 concrete channel entrance. Figure 7 illustrates the water surface elevation for existing conditions at full capacity. When the flow exceeds 3,200 cfs, the excess is out of the channel.

Figure 7: Estimated floodwater surface elevation profile for 3,200 cfs under Existing Conditions without Lagunitas Road Bridge



Source: FGC and Stetson 2006

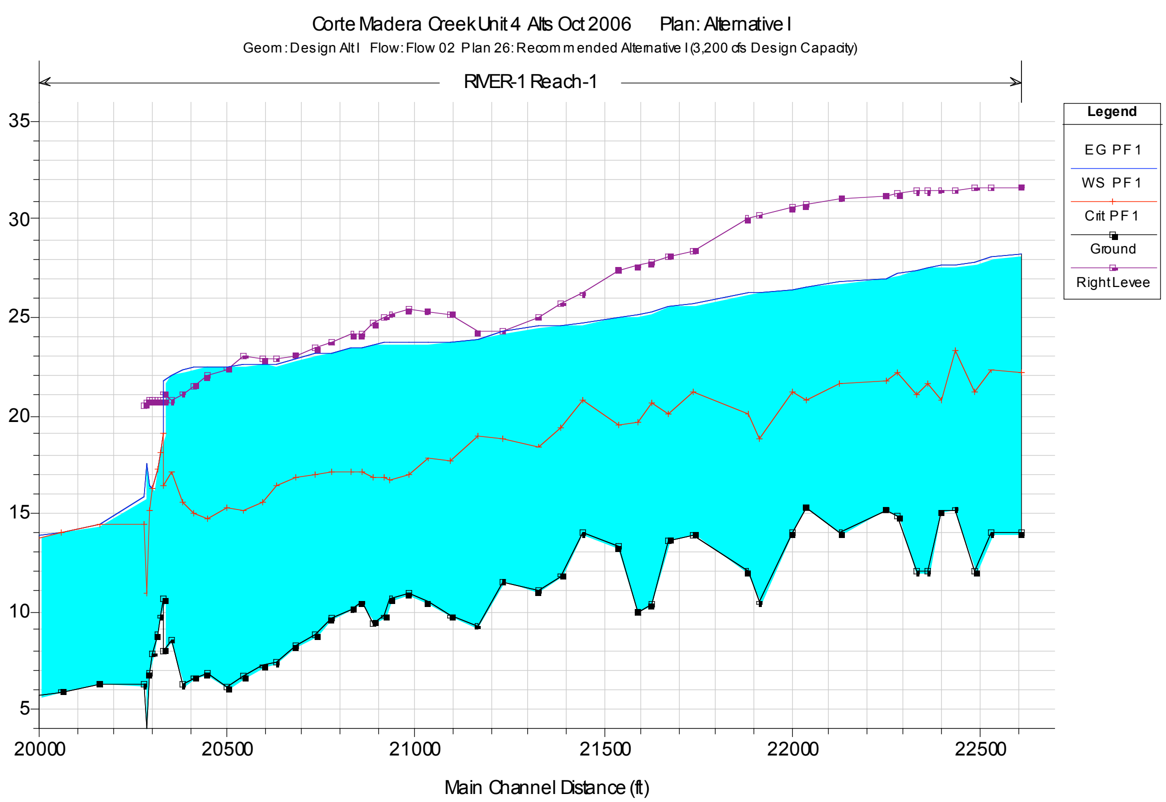
10 Modeling including the Lagunitas Road Bridge was also done for the existing condition for use in environmental review and the permitting process. Results are in FGC and Stetson (2006).

4.2 Option 1: Fishway Replacement with No Change in Capacity

Option 1 would be implemented if the choice is made to leave the capacity of Unit 4 unchanged (no project). In that case, it would be necessary to treat the barrier to salmonid passage at the fish ladder to avoid continuing violation of the federal Endangered Species Act. Option 1 would replace the wooden fish ladder with a state-of-the-art concrete pool-and-chute fish ladder within the upstream 68-ft length of the existing Unit 3 concrete channel; this fishway would meet current fish passage criteria.

The estimated design capacity would remain at 3,200 cfs, again producing a maximum 1.1 ft overbank flow at the west bank immediately upstream from the Unit 3 concrete channel entrance. Figure 8 illustrates estimated water surface elevations for Option 1.

Figure 8: Estimated water surface elevation profile at 3,200 cfs for Option 1

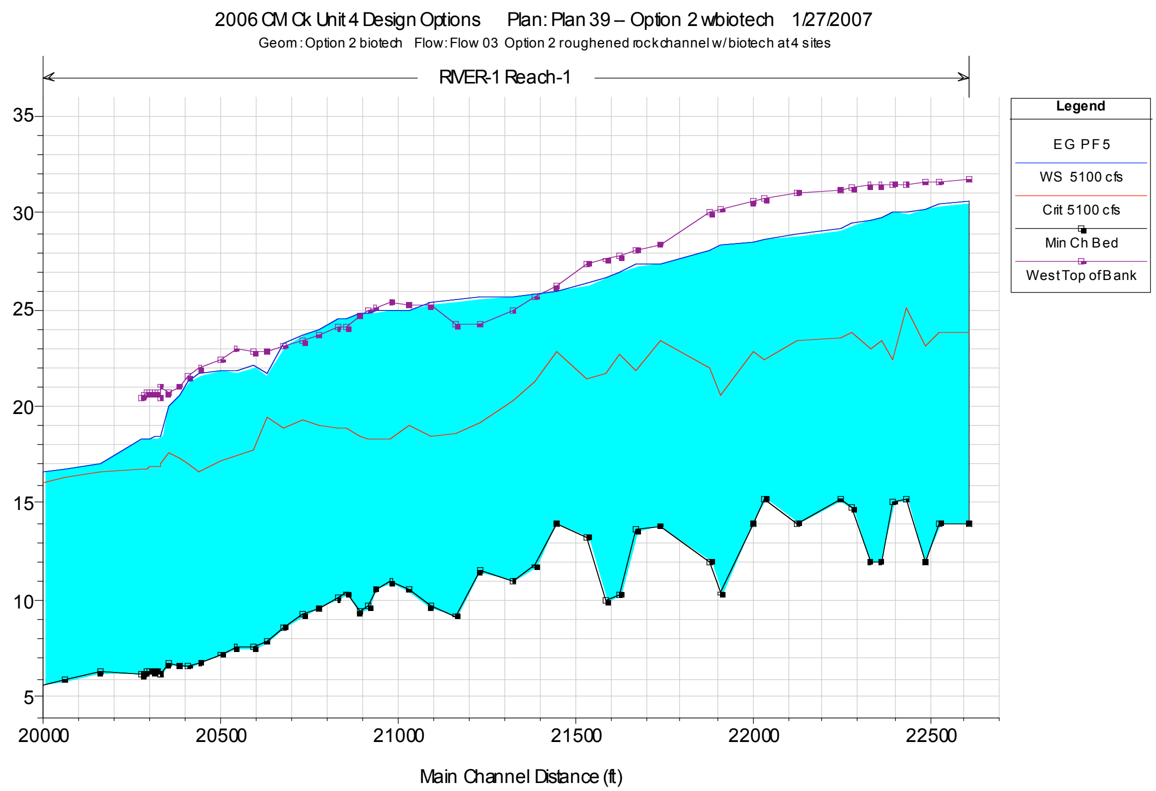


Source: FGC and Stetson 2006

4.3 Option 2: Option 2: Natural Grade Roughened Rock Channel, Biotechnical Bank Stabilization at Five Sites

Option 2 would remove the existing grade control and fish ladder structure, add the roughened rock channel upstream of Unit 3, and regrade channel banks and add biotechnical bank stabilization at 5 sites (see Section 2.3). Implementing the bank regrading and biotechnical stabilization would lower the floodwater surface elevations 0.5 ft throughout most of the study reach, but not increase the design flood capacity by more than 1,900 cfs (Figure 9).

Figure 9: Estimated water surface profile at 5,100 cfs in the Unit 4 reach Option 2



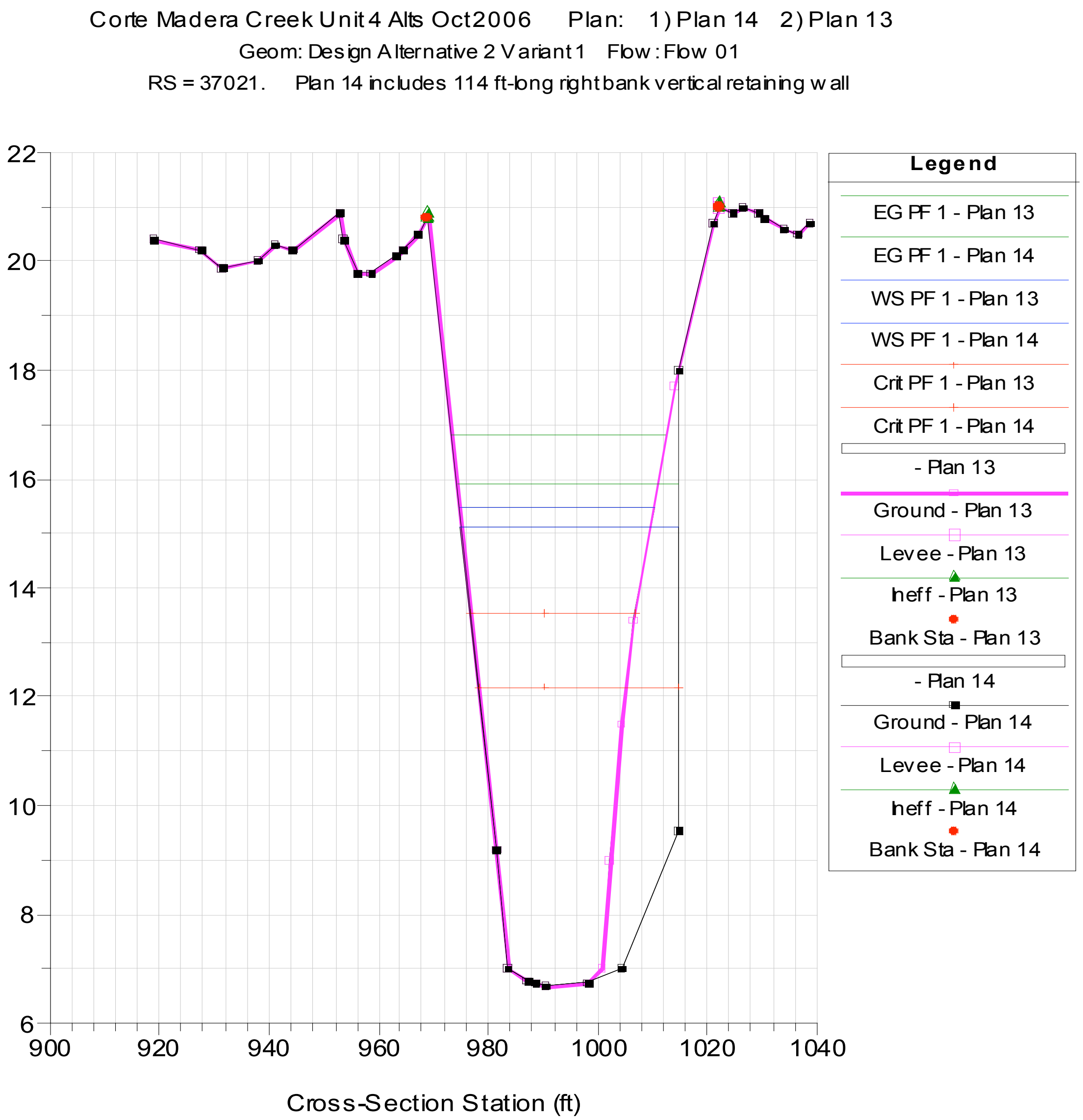
4.4 Option 3: Natural Grade Roughened Rock Channel, Biotechnical Bank Stabilization at Four Sites, Wall Configuration 1 (mid-bank 114 ft long)

Option 3 is intended to provide grade control and improve fish passage with a natural grade roughened rock channel type fish passage structure, and increase flood capacity to the extent feasible using limited vertical retaining walls while preserving the entire west bank riparian corridor.

With the existing grade control fish ladder structure removed, the next upstream flood-flow constraint is in the downstream 100-110-ft length of Unit 4 where the channel is approximately 20-ft wide, substantially less than the 32-ft width of the Unit 3 concrete channel. Widening the channel the necessary 10-15 ft would require installation of an approximately 114-ft long maximum 9-ft high vertical retaining wall at mid-bank immediately upstream of Unit 3. Virtually all of the existing native riparian canopy-forming vegetation in the proposed grading area (native willow) was recently removed during emergency construction access to construct the east bank riprap bank at 21 Sir Francis Drake Blvd immediately following the December 31, 2005 flood. The grading activities would therefore have negligible or no impacts on the existing riparian corridor.

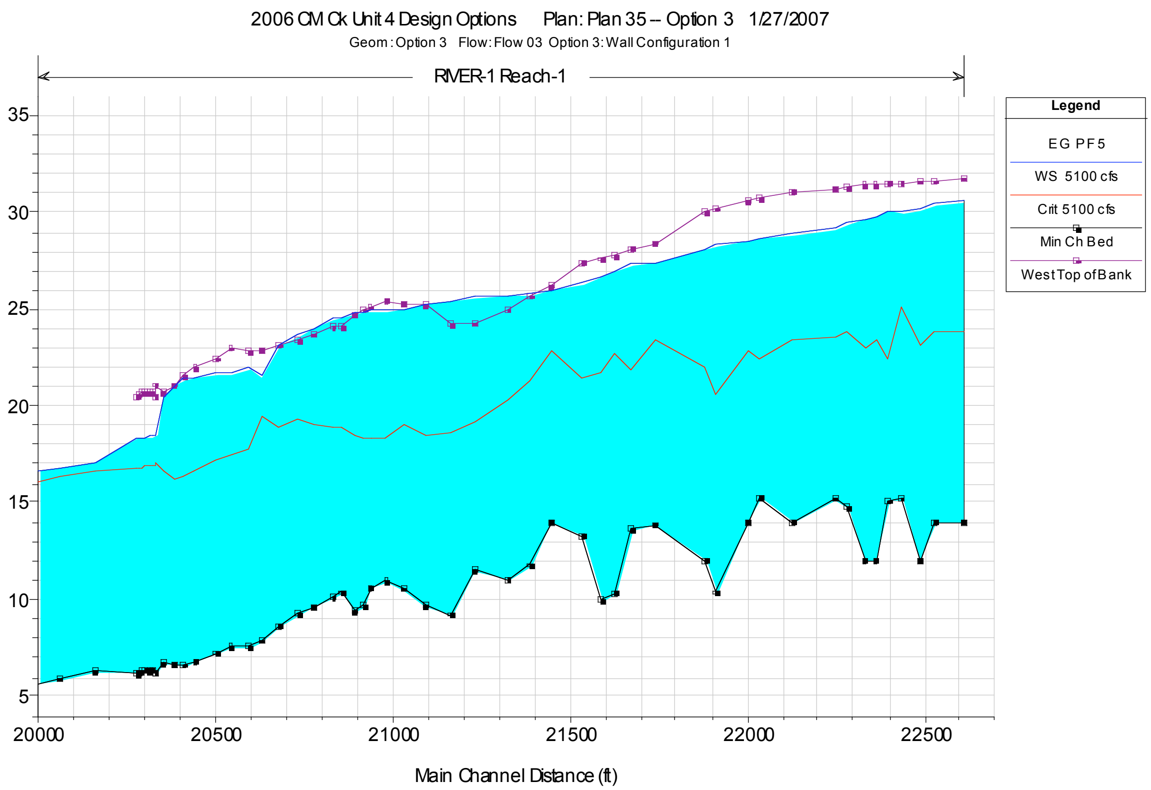
Figure 10 shows the typical modified cross-section profile for Option 3 where the existing sewer line passes under the west bank before continuing under the channel bed. Option 3 would produce virtually the same floodwater surface elevation profile as Option 2 and does not increase the design flood capacity to more than 5,100 cfs (Figure 11).

Figure 10: Comparison of cross-section geometry for the unmodified bank (pink) and Option 3 (gray) at River Station 370+21 ft, illustrating the location of Wall Configuration 1



Source: FGC and Stetson 2006

Figure 11: Estimated water surface elevations at 5,100 cfs for Option 3



4.5 Option 4: Natural Grade, Roughened Rock Channel, Biotechnical Bank Stabilization at Three Sites, Wall Configuration 2 (mid-bank, 550 ft long)

Increasing the Unit 4 design capacity by more than 1,900 cfs would require further widening the channel at the narrow constriction in the vicinity of the existing east bank vertical concrete retaining wall at 27 Sir Francis Drake Blvd. Option 4 would achieve this by reconfiguring and extending upstream the 114-ft long retaining wall simulated Option 3 to provide for a 40-ft minimum bankfull channel width from the inlet of the Unit 3 channel upstream to the existing encroached west bank private residential vertical steel sheetpile bank stabilization structure at 1 Sylvan Lane. (Option 4 would achieve only a 36-ft wide channel width at the existing garage cross-section within east bank biotechnical bank stabilization Site 1; see Section 2.3 and footnote no. 7).

Option 4 includes an approximately 550-ft long mid-bank vertical concrete or steel sheetpile retaining wall extending from the Unit 3 channel upstream to near the existing Lagunitas Road Bridge west bank downstream concrete wingwall. By careful design of the retaining wall alignment, this option preserves the majority of existing native riparian canopy forming trees in the Unit 4 reach, and the overall character of the corridor and the aesthetic backdrop it creates for public space on the Ross Town commons. Figure 2, the plan view of components described in Section 2, shows the configuration of the proposed retaining wall, and the trees to be removed under Option 4, and the resulting reduction in the canopy cover.

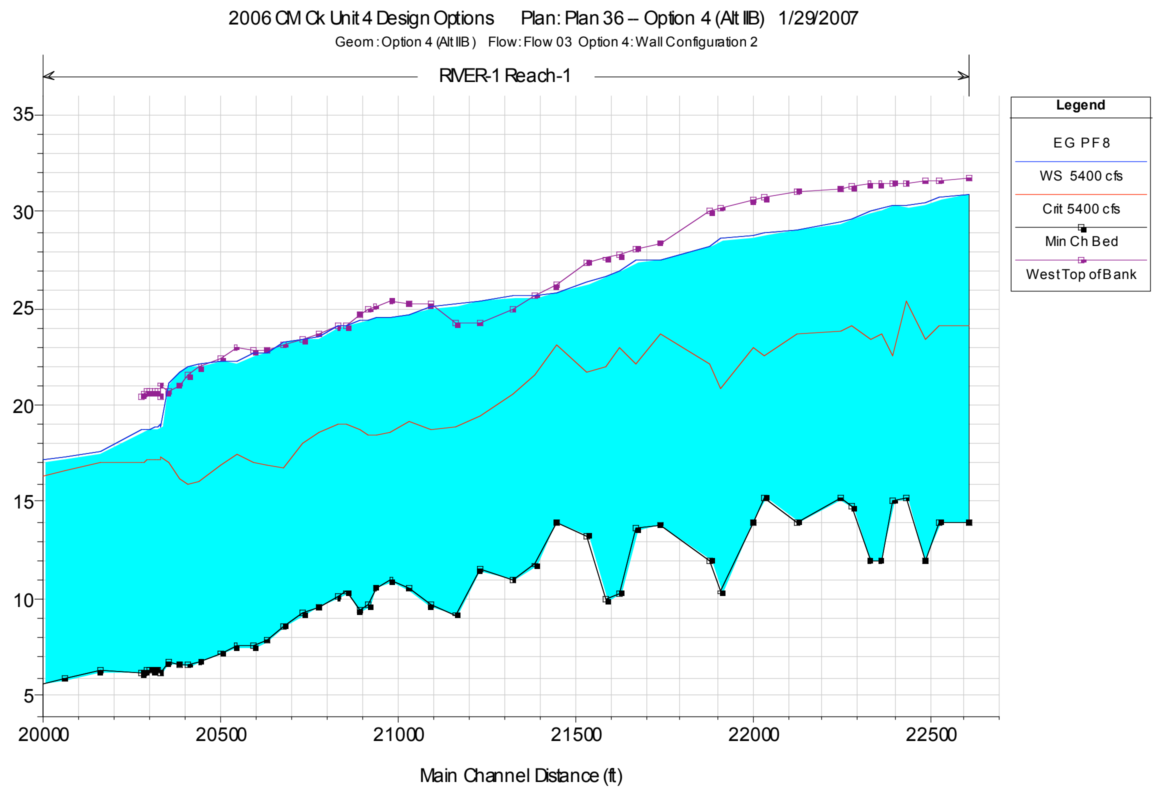
First, widening the channel and installing the vertical wall some distance away from the existing toe of the channel bank allows the existing native alders to be saved and not removed. It is important to note that the existing alders are rooted at or within 1-2 vertical feet from the low-flow water surface, at the same elevation as natural free-forming gravel bars. Therefore, removing the alder and grading the channel bed down would produce a negligible additional flood management benefit – the gravel bars will simply reform at their former, pre-excavated, elevation during the first water year. It follows that preserving existing alders does not constrain maximum achievable design channel capacity. Furthermore, the existing alders have few horizontal branches and are rooted in lines parallel to the direction of flood flow, minimizing their hydraulic effect.

Second, the 550-ft long vertical retaining wall alignment was designed to substantially achieve the flood management objective while avoiding removal of the largest native riparian canopy forming trees near the top of the bank (primarily maple and ash). By saving the native alders along the toe of the bank and the maple and ash near the top of the bank, the majority of the canopy is preserved and the overall aesthetic character of the corridor would be substantially the same. Figure 3 shows, in concept, how this design would save toe-of-bank and top-of-bank trees, but necessarily remove the mid-bank trees. This way, the majority of the canopy cover is retained, as shown in Figure 2. Figure 5 shows an example cross-section profile at River Station 373+74 ft, located approximately 400 feet upstream from the fish ladder, where an existing alder is preserved at the toe of the bank, and two existing ash are preserved near the top of the bank. Figure 4 shows, in concept, the grading effects at other cross sections in the study reach.

Option 4 also includes two east bank biotechnical bank stabilization projects made necessary at two locations where existing west bank structures and utilities prevent achieving the 40-ft minimum channel width with additional west bank grading. The first site is on private residential property at 23 Sir Francis Drake Blvd across from the existing vertical steel sheetpile wall at the back of the Ross Post Office (Figure 1). The site is situated between an existing rock-filled gabion mattress-wall structure at 25 Sir Francis Drake Blvd, and an existing approximately 1(H):1(V) sloped riprap covered bank at 21 Sir Francis Drake Blvd. The upstream approximately 68-ft long portion of the site would be graded back to maximum 1.25(H):1(V) slope to meet the minimum width requirement and not necessarily destabilize the existing garage foundation at the proposed top-of-bank design. The finished slope would be hydroseeded, covered with biodegradable geofabric, and vegetated with native riparian canopy-forming trees (e.g., native willow and alder on the lower slope and native ash, maple, and oak on the upper slope). The bank section immediately below the existing garage foundation may also require lining with vegetated riprap. The entire graded area would be protected with 18-24-inch minimum diameter riprap placed along the toe of the existing bank to extend the hydraulic profile of the existing gabion basket mattress at 25 Sir Francis Drake Blvd. The approximately 68-ft long toe protection would be constructed to form a bench at the same elevation as the existing alders are rooted across the channel from the site, with sufficient void spaces on the top of bench and near the toe of the fabric and rock covered upper bank to allow backfill with sand-and-gravel and planting 1-gallon native alder. Three existing native trees on the mid-bank would be removed.

The estimated design flood capacity of Option 4 is 5,400 cfs (Figure 12).

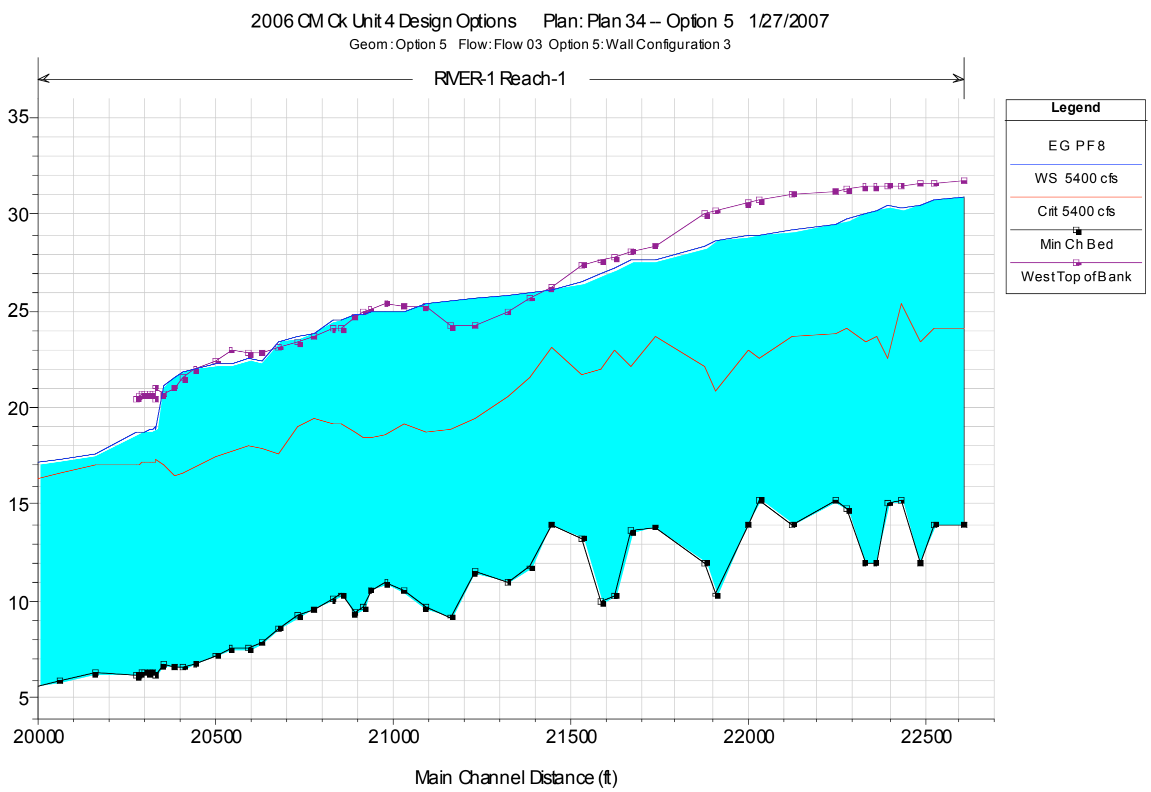
Figure 12: Estimated water surface elevation for Option 4



4.6 Option 5: Natural Grade, Roughened Rock Channel, Biotechnical Bank Stabilization at Three Sites, Wall Configuration 3 (mid-bank, 114 to 550 ft long)

Option 5 is a variation of Option 4 that would replace Wall Configuration 2 with Wall Configuration 3 and thereby reduce the total length of the retaining wall from 550 ft to approximately 275 ft. Wall Configuration 3 is a combination of the 114-ft long Wall Configuration 1 and an approximately 160-ft long west bank vertical retaining wall designed to achieve a 32-ft (not 40-ft) minimum channel width along the length of the east bank retaining wall at 27 Sir Francis Drake Blvd. Option 5 floodwater surface profiles are approximately 0.5 ft higher than Option 4 profiles in places along the study reach, but the overall design flood capacity is the same, about 5,400 cfs (Figure 13).

Figure 13: Estimated water surface elevation at 5,400 cfs for Option 5



5: General Conclusions

This section describes several issues that bear on the final decision about the appropriate measures to be implemented in Unit 4.

5.1 Definition of Unit 4 Design Channel Capacity

The definition of Unit 4 design channel capacity is critical to the comparative evaluation of the recommended options. Recall that the Corps' 1999-2000 design alternatives used a singular definition of channel capacity -- the 25-ft Lagunitas Road Bridge deck elevation. Although the design alternatives described in the October 2006 technical memorandum (FGC and Stetson) sought to apply a reach-scale definition of channel capacity (discussed in Part 1), the hydraulic effect of the transition to the relatively narrow Unit 3 concrete channel causes the downstream most 200-ft length of Unit 4 to overtop its banks at a significantly lower discharge than the remainder of the study reach. This way, the narrow Unit 3 channel limits the maximum Unit 4 design channel capacity. Still, careful evaluation of the model-calculated water surface elevation profiles shows that design options with the same design capacity would produce different water surface elevations in the upstream remainder of the study reach that would have an impact on, among other things, the design feasibility and construction cost of Lagunitas Road Bridge replacement. Moreover, installing low (1-2 ft high) temporary (e.g., sandbags), or permanent (e.g., concrete) floodwalls in the downstream most 200-ft length of Unit 4 and other "weakest link" overbank flow sections could slightly increase the maximum Unit 4 design channel capacity. Permanent low concrete floodwalls could be architecturally designed to appear and function as bench seating along the pedestrian right-of-way.

5.2 Consideration of Temporary or Permanent Low Floodwalls in Unit 4

Several factors appear to limit the feasibility and flood management cost-benefit ratio of installing low floodwalls in Unit 4. First, the east bank residential property ground elevations are generally 0.5-1.0 ft lower than the west bank top-of-bank elevations. Temporary or permanent west bank floodwalls would slightly exacerbate flooding depths on the east bank residential properties. Either there should be an equal elevation floodwall installed along the top of the east bank, or the residential properties should be floodproofed according to the design west bank floodwall elevation profile.

Second, as an alternative to low floodwalls along the west top-of-bank, permanent low concrete walls along the western edge of the parking lot (away from the creek) could be configured to direct local overbank flow past the post office and back to channel at the upstream end of the Unit 3 channel where the floodwater surface elevations are reliably lower than the top of the concrete channel wall. This "second stage" floodwall would need to be discontinuous at automobile, bicycle, and pedestrian throughways—gaps where temporary sandbag walls would need to be installed during early flood warnings to make the second stage flood wall continuous.

Third, temporary or permanent floodwalls are considered for the purpose of eliminating shallow overbank flow in the most vulnerable sections of the study reach, as reflected by the 2006 model results. However, these model results are not calibrated. Indeed, high water marks from the December 31, 2006 flood were rather uniformly between 1.0 and 1.5-ft high along the existing 625-ft long chain link fence along the top of the west bank. However, the shape of the model-calculated water surface profile for 2005 existing conditions

(Figure 1) does not match the shape of the December 31, 2005 profile well, in that it shows greater overbank depths in the lower 200-ft length of Unit 4 and no overtopping upstream. This is partially a model anomaly; the model does not contain a wide floodplain area on the west bank. Therefore, the model, in effect, "keeps" all overflow in the channel—it does not calculate the lower in-channel discharge that would result from overbank flow leaving the channel and flowing into downtown Ross. That is to say, the modeling documented in this memorandum is in-channel modeling for the purposes of determining in-channel design channel capacity. For modeling higher discharges or for calibrating to measured high water mark profiles, such as the December 31, 2005 flood profile, it would be more correct to model the study reach as split-flow, designating the existing right bank top-of-bank profile as a parallel overflow weir. Stetson Engineers is currently developing steady flow and unsteady flow models of the entire Corte Madera Creek mainstem channel calibrated to the December 31, 2005 flood discharge and profile. When completed, these models may provide a better estimate of the Unit 4 existing conditions and design channel capacities.

The detailed design, feasibility and performance of these design options and any variations that would use floodwalls to further increase channel capacity also depend on results of the overall Ross Valley Watershed Program, including successful identification, design, funding, and implementation of flood management improvement projects upstream on San Anselmo Creek to, among other things: increase channel capacity in downtown San Anselmo; increase Unit 2 and Unit 3 channel capacity with dredging; low floodwall parapets and/or channel widening; and routing floodplain and Murphy Creek flows originating in San Anselmo and Ross through Kentfield to return them back to Corte Madera Creek. Selection of the preferred alternative design and design capacity for Unit 4 should depend both on what design capacity is achieved upstream (and considering correct hydraulic modeling of peak tributary inflows from Ross Creek), and how flood flows entering Kentfield are to be handled.

5.3 Unit 3 Transition Appears an Intractable Hydraulic Constraint

The October 2006 modeling and design work has shown that the transition from the broader Unit 4 channel to the narrower Unit 3 concrete channel is an intractable hydraulic constraint. The design alternatives and variants considered included longer and more gradual (plan view) transitions into Unit 3, all of which made slightly worse, not better, the hydraulic effect of the transition compared to existing conditions. A practically infinite number of design alternatives and variants could be tested with the model, including a wide range of approach angles and transition lengths, but none of the small number of combinations selected over a wide range for testing in this study proved the hydraulic constraint could be significantly mitigated, without, for example dismantling and reconstructing the upstream several hundred feet of the Unit 3 concrete channel to provide for a very gradual transition from the Unit 4 design minimum channel width to the 33-ft Unit 3 channel width.

5.4 Feasibility of Biotechnical Bank Stabilization

In general, biotechnical bank stabilization techniques are feasible at least five sites in the Unit 4 study reach. This modeling work has shown that implementation of bank regrading and biotechnical bank stabilization at the two east bank sites provides a worthwhile flood management benefit. Regrading the west bank sites, which are already relatively steep under existing conditions, would have a much smaller flood benefit. Vertical retaining walls are required along the west bank to provide for measurable increases in channel capacity while saving a significant portion of the existing canopy-forming trees. The October 2006 design alternatives minimize the aesthetic impacts of vertical walls by limiting their application to the west bank where they can only be seen from Lagunitas Road Bridge and the private residential properties on the opposite bank. Other aesthetic improvements can be made during the detailed design phase, including options for naturalistic rock masonry facing.

Purely biotechnical bank stabilization treatments at two east bank sites were identified where it was necessary to widen the channel and the west bank. These could not be widened further without removing existing public and private infrastructure. At the Town Hall property (Site No. 2), sufficient widening can be accomplished without impacting the existing pavement area near the top of the bank. At the private 23 Sir Francis Drake Blvd property (Site No. 1), the amount of channel widening that can be accomplished is limited by avoidance of the existing garage building foundation at the top of the bank. If the landowner is willing to modify or reconstruct the garage building as part of the biotechnical stabilization at the site, then an incremental flood benefit would result.

It is also important to note that vertical retaining walls would also have geomorphic and environmental benefits that are not typically recognized. Because vertical walls allow the channel to be more substantially widened than biotechnical measures, they would essentially create more room for the creek to perform its natural processes of channel meandering and floodplain sediment deposition—the very processes that support healthy aquatic habitats and self-sustaining riparian plant communities. Viewed this way, options that include these walls can be seen to provide for long-term benefits to both the environmental and natural aesthetic attributes of the stream corridor. Wall Configuration 1 and 3 only slightly widen the channel compared to west bank biotechnical measures applied at the same constrictions. Wall Configuration 2 more substantially widens the channel; only Wall Configuration 2 could be said to deliver some unquantified environmental benefit of "creating more room." The October 2006 design alternatives (FGC and Stetson 2006) included Alternative III, which would use a much longer, higher retaining wall than Wall Configuration 2. Because of the intractable hydraulic constraint that is the narrow Unit 3 channel (see Section 5.3), Alternative III would not increase the overall design flood capacity of Unit 4 to more than 5,400 cfs. But it would reduce the floodwater surface elevation in places along the study reach, including the vicinity of Lagunitas Road, and substantially widen the channel bed area – i.e., "create room" for natural geomorphic processes. This would be at the expense of most of the existing west bank riparian corridor; only the existing alders rooted along the toe of the bank could be preserved under Alternative III. See the full technical memorandum for more information about Alternative III.

5.5 Hydraulic Design for Lagunitas Road Bridge Replacement

The detailed hydraulic modeling work completed in the October 2006 full technical memorandum showed that the channel is sufficiently wide in the vicinity of the existing Lagunitas Road Bridge. Widening the channel at the bridge cross-section as part of the planned replacement of the bridge would provide negligible, if any, hydraulic benefits. However, regrading and biotechnically stabilizing the bank upstream from the bridge (Site No. 2 described in Section 2.3) would substantially reduce floodwater surface elevations upstream from the bridge. This modeling work assumed that the bridge would be replaced according to a hydraulic design specifically intended to exert no hydraulic effect on creek flows up to the design channel capacity. This is the same thing as assuming the replacement bridge structure would have: practically the same vertical concrete abutments as existing; no piers; and a clear-span bridge deck with a minimum elevation equal to or greater than the model-calculated design channel capacity flow water surface elevation at the bridge location. Model results displayed in Parts 3 and 4 of this summary report are sufficient for determining the minimum design low-chord elevation for each of the design options. The actual hydraulic effect of preliminary and final bridge replacement designs would need to be modeled for the preferred design option and design flood capacity discharge.

6: References Cited

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