Philip Williams and Associates, Ltd., "Newhall Ranch Tributary Channel Design Guidelines" (November 20, 2008)

NEWHALL RANCH
TRIBUTARY CHANNEL DESIGN GUIDELINES

Prepared for

Newhall Land

Prepared by

Philip Williams & Associates, Ltd.

November 20, 2008

PWA Reference # 1820

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1. DESIGN METHODOLOGY

This guideline presents the design methodology that will be used for the hydromodification control and enhancement program for the tributary channels within the Newhall Ranch Specific Plan (NRSP) projects. This guideline focuses on the physical parameters of the channels, providing design guidelines to create stable stream channels that conform to Los Angeles County Department (LADPW) policies while supporting the desired ecosystems (in-channel habitat, riparian, wetland etc) following project implementation. These physical parameters include channel width, depth, slope, and planform. The approach focuses on developing these parameters based on the future flow and sediment regime, using an integrated geomorphic and engineering approach that predicts stable characteristics, and uses structures only in locations where erosional forces will exceed the natural stability of the channel. All structures (bank and channel bed protection) are designed to mimic natural features and use either biological, biotechnical (combination of structural and vegetative methods) or structural methods to provide stream channels that are stable, attractive and support the desired habitat elements.

Channel width, depth and slope are interdependent. In keeping with standard stream restoration design practices, a "slope first" design approach will be used in which channel equilibrium gradient is determined, followed by width and depth. The difference between the existing and future (stable) slope then determines the amount of the total gradient that must be stabilized using grade control structures (GCSs), which may be designed as a sequence of "step-pools." These step-pool structures are then designed to be hydraulically-stable during the LADPW design flow (capital flood or "Q_{cap}").

Three different methods of calculating channel width, depth and slope that fulfill the LACDPW and Newhall Ranch Specific Plan Sub-Regional Stormwater Mitigation Plan (NRSP Sub-Regional SWMP) requirements will be used that are based on performance of channel designs in a variety of settings. Channel width and depth will be calculated assuming a compound channel cross-section with a low-flow channel and adjacent floodplain terrace within the overall channel section.

The key objectives for channel design are:

1. Accommodate runoff flows from existing and future development.
2. Stabilize the channel bed and banks so that they do not degrade.
3. Preserve the waterway and canyon characteristics and environment, as applicable.
4. Protect existing and proposed infrastructure and homes from being endangered by erosion and excessive movement of the stream.
5. Minimize riparian and bank disturbance during construction, where applicable.

6. Implement improvements that are the most compatible with the environment and character of the region, yet sustainable on a long-term basis.

7. Allow for construction access and maintenance activities.

8. Minimize channel maintenance requirements

2. DESIGN DISCHARGES

The dominant discharge will be used as the design basis for the main low flow channel, in keeping with standard geomorphic practices. Dominant discharge is the flow that cumulatively transports the majority of sediment over a long period of time. This analysis approach assumes dominant discharge is equivalent to the 2-year flow for purposes of channel design. Using a long-term continuous rainfall-runoff hydrologic simulation for the Newhall Ranch watersheds, Geosyntec (2006) calculated the 2-year recurrence interval storms for the post-developed conditions. These 2-year storms will be used as the design event for the low flow channel, in so far as hydraulic analysis shows that these designs are also consistent with the LACDPW approaches.

3. CHANNEL SLOPE

The tributary channel slopes will be designed using LA County methods. The resulting slope will then be verified using the erosion potential (Ep) method (described in detail below) and field geomorphic data, and adjusted if necessary. The reasonableness of the design slopes will also be verified using actual channel slopes measured from undeveloped watersheds in the region (described in detail below).

3.1 METHOD 1. LOS ANGELES COUNTY DEPARTMENT OF PUBLIC WORKS METHODS

Both LACDPW methods of calculating equilibrium channel gradient (Table 1) will be applied. The first is an empirical method that is suitable for rapid analyses of small channels. The second is an analytical method, using sediment transport equations, that is more complex.

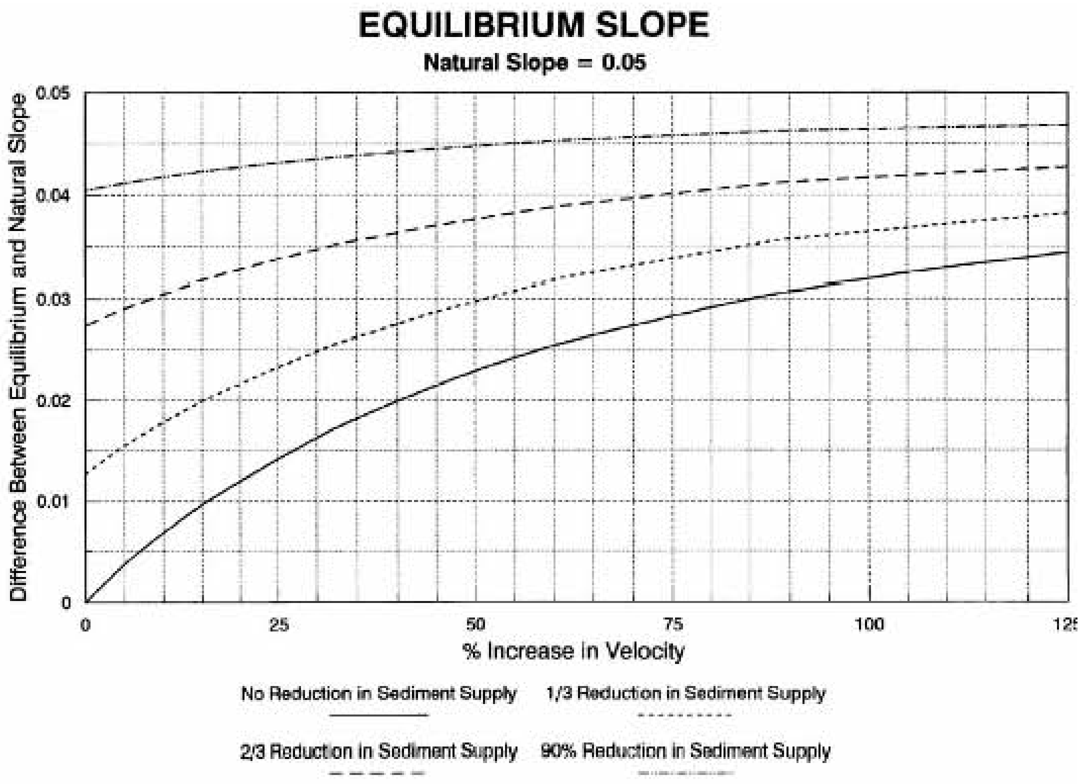
Table 1. Summary of LA County Methodologies

	Method 1a – LACDPW empirical method	**Method 1b – LACDPW analytical method**
Inputs	Existing conditions flow velocity Proposed conditions flow velocity Existing conditions channel slope Proposed conditions reduction in sediment supply	Upstream water and sediment inputs
Events Assessed	Qcap and 0.25Qcap	0.25Qcap
Approach	Nomograph based on empirical relationships for LA County. Use nomograph to identify slope reduction for both events and use the lower of the two slopes	Use sediment transport modeling to size channel to convey water and sediment at design flows without erosion and use the lower of the two slopes
Output	Reduction in existing slope required to achieve equilibrium	Equilibrium width, depth and slope of channel

3.1.1 <u>Method 1a: LACDPW Empirical Method</u>

The LACDPW empirical method involves comparing pre- and post-project channel velocity and sediment availability for Qcap and 0.25 Qcap. Equilibrium slope is estimated from the nomograph (Figure 1) based on changes in velocity and sediment supply. PWA developed a spreadsheet to automate interpolation from the nomograph and calculate the resulting stable channel slope.

Figure 1. Nomograph for Estimating Equilibrium Slope



Source: LA County Dept of Public Works, 2006. Appendix C.

3.1.2 Method 1b: LACDPW Analytical Method

This method is specified for soft bottomed channels with levees. The approach is based on applying a sediment transport equation for pre- and post-project conditions and iteratively adjusting channel slope until post-project sediment transport is equal to pre-project. The method requires selection of the most appropriate of the following sediment transport equations:

1. Meyer-Peter, Muller equation
2. Einstein bed load equation
3. Einstein suspended load methodology
4. Colby methodology

Reid and Dunne (1996) review a large number of sediment transport equations for suitability based on the number and accuracy of field verifications on different types of channel. They recommend the following applications (Table 11, p.100):

- Meyer-Peter/Muller model: gravel bedded and braided channels, and small sand bedded streams
- Einstein and Colby: medium and large sand bedded channels

3.2 VERIFICATION USING EROSION POTENTIAL METHOD

Erosion potential (Ep) is a measure of the change in the long-term, cumulative effective work done on the channel by hydraulic forces between a pre-project and post-project condition, which represents the change in sediment transport capacity. 'Effective work' is calculated based on the difference between the applied boundary shear stress and the critical shear stress of the boundary materials or bed sediments represented by the complete grain size distribution. The ratio between existing and proposed effective work or sediment transport capacity (Ep) is used to evaluate whether the designed channels will be stable under proposed flow conditions. The methodology uses continuous rainfall-runoff simulations in the EPA Storm Water Management Model (SWMM) for 31 years of available record. The resulting flow time series are applied to a sediment transport model to calculate Ep for a series of existing and proposed cross sections.

Proposed conditions are typically compared to the existing condition; however, for channel design where the existing condition is unstable, the baseline used for comparison is based on stable reference reach(es). When reduction in sediment supply is an important physical element in stable channel conditions, the target Ep is adjusted accordingly. When post-developed flows are increased and reductions in sediment supply are not important, the target ratio of existing and proposed Ep is set to 1.0. That is, the proposed design attempts to match the baseline conditions (i.e., the future sediment transport condition is equal to the existing sediment transport condition). When reduction in sediment supply is important, an equivalent reduction in the transport capacity is needed. For example, a project that reduces sediment supply to 30% of its baseline level requires the transport capacity to also be reduced to 30% of its baseline condition; i.e., Ep = 0.30.

A correlation between observed field conditions (channel stability) and predicted erosion potential for 49 cross-sections within four separate California watersheds showed that as the erosion potential begins to exceed the target by 20 to 30 percent, the probability of stream channel instabilities begins to increase rapidly (SCVURPPP, 2005). The Ep verification methodology therefore incorporates a risk-based approach that limits the variance in erosion potential to ±20% of the target, as the risk of hydromodification impacts is low in this range.

Table 2. Description of Ep Verification Method

	Verification Method - Geosyntec Application of the Erosion Potential Model
Inputs	Runoff from continuous rainfall-runoff model (SWMM) Reduction in sediment supply Bed particle size distribution, bank material type, vegetation density Existing and proposed channel geometry and longitudinal slope
Events Assessed	Continuous range of geomorphically significant flows
Approach	1. Compute work done and sediment load transported for existing geometry and flow conditions using range of sediment transport and work equations. Identify stable and unstable sections. 2. Scale target Ep based on reduction in sediment delivery (e.g., 40% reduction in sediment requires 40% reduction in E_p). Identify the appropriate baseline condition for comparison. 3. Calculate Ep for the proposed channel design at several cross sections. 4. Refine slope until future Ep does not deviate from the target Ep by more than ±20%.
Output	Slope of channel that is within 20% of target Ep, adjusted for sediment reduction.

3.3 VERIFICATION USING FIELD DATA AND SAM SIMULATIONS

3.3.1 Field Data

In addition to verification using the Ep method, we assess the proposed channel design using field data from the Newhall Ranch area. This check is performed to assess the geomorphic stability of the creek. Data on equilibrium slope were collected in Newhall Ranch by measuring channel gradient in stable channel reaches. These are often located immediately upstream of grade control structures. These were compared with watershed area, (used as a surrogate for channel forming discharge). Although the data have a low R^2 value reflecting scatter around a central regression line, they provide an *envelope* of actual observed field conditions from the creeks in question. While this envelope of data should not be, and is not, the sole basis for design, it is an important line of supportive evidence with which to verify the estimates provided by the sediment transport models that are also used in the analysis. When using sediment transport models it is important to back them up with as much additional field evidence as possible. The resulting plot is shown in Figure 2. A measure of stable channel gradient under post-development conditions can be determined by looking at the channel gradient of watersheds with the same runoff as the post development watershed. For example, as a first step approximation, a 1 square mile watershed in which post-development runoff is doubled will lead channel slopes to adjust to a gradient appropriate to a 2 square mile watershed, assuming the same sediment delivery.

3.3.2 Sam Simulations

To compensate for reductions in sediment supply we performed a sensitivity analysis to determine the degree to which reductions in sediment supply affected equilibrium slope. We ran a series of simulations using the USACE Stable Channel Design Model SAM. In these simulations we simulated equilibrium slopes and then progressively cut back sediment delivery to calculate the resulting channel gradient adjustment. The resulting graphs (see Figure 3) allow us to calculate the equilibrium channel gradient for a watershed in which water flow has increased and sediment supply has decreased. We used this method as a check to ensure the channel designs were geomorphically-appropriate to the site.

Figure 2. Equilibrium Slope for Rural Reference Reaches

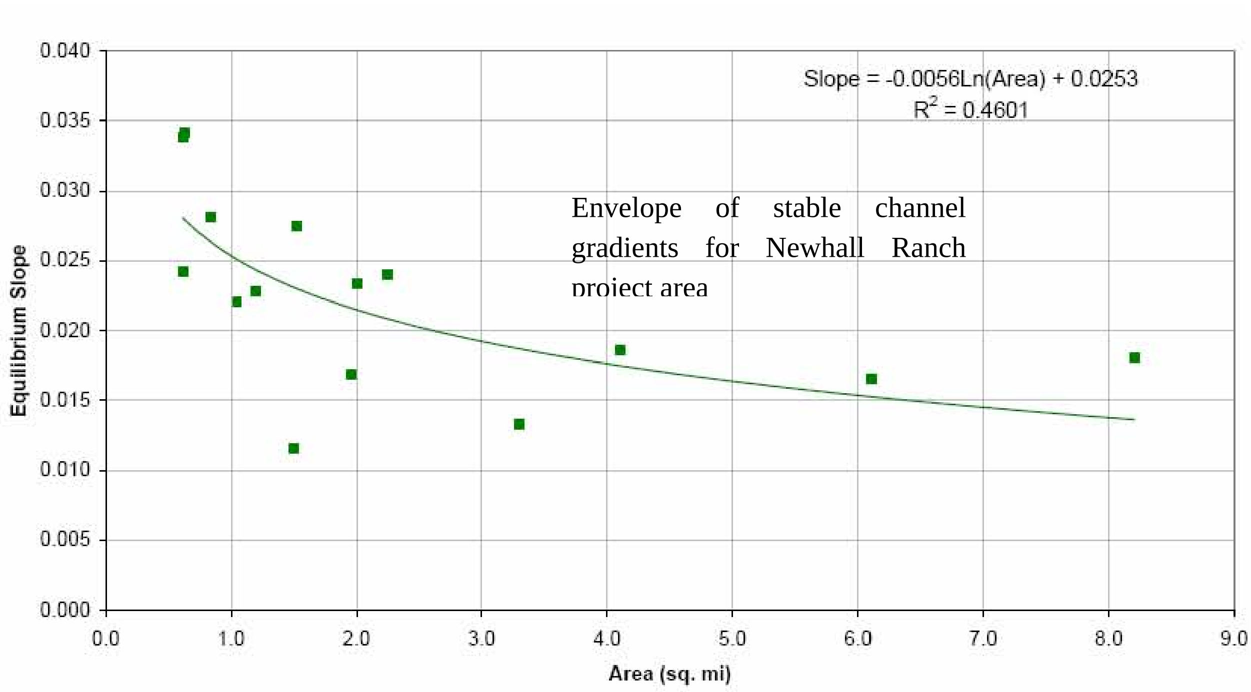
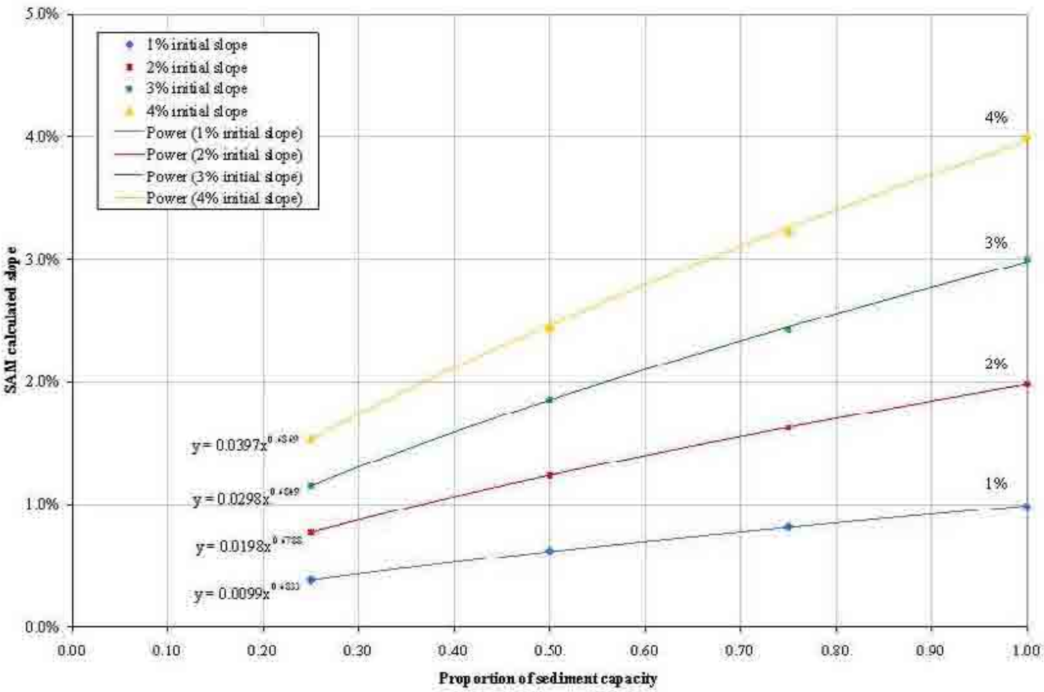


Figure 3. Sensitivity of Channel Slope to Reductions in Sediment Supply



3.4 SELECTION OF DESIGN CHANNEL SLOPE

Each of the above design approaches produces a slightly different estimate of stable slope. Based on these estimates, we will select a design slope that falls between the high and low end of the estimates. This slope will be tested using the Ep method and adjusted as necessary to meet the appropriate Ep standard. In general, this approach produces a relatively conservative estimate of the stable channel slope, to insure that stabilization structures are not undermined. In order to anticipate possible aggradation impacts on flood control performance, the highest of the previously estimated design slopes will be used to calculate potential channel sedimentation between drop structures, and hence flood capacity.

3.5 DESIGN SLOPE IMPLEMENTATION

Where extensive development will take place in the watershed and plans call for channel regrading (Long Canyon and Potrero Canyon), or where the existing channel is degraded and some development will take place in the watershed (Lion Canyon), step-pool design structures (described in Section 5) will be set at the selected channel slope.

Where channels are not degraded and less extensive development will take place in the watershed (San Martinez Grande Canyon and San Martinez Chiquito Canyon), grade control structures will be used to maintain the existing slope.

The north bank tributary channel design approach can be summarized as follows:

1) Develop existing condition floodplain and creek hydraulic characteristics. (HEC-RAS)

2) Minimize impacts to existing condition floodplain. As a result of reducing the development impacts to the floodplain, the amount of environmental and hydraulic impacts from the proposed development is minimized.

3) Creek bank flood protection (soil cement, rip rap or other suitable method) is located to provide for bank erosion protection and to provide flood protection from the LACDPW Capital design flood event. In most cases, the bank protection is buried with soil at a 3:1 slope over the hard bank protection. The soil backfill slope will vary from flatter to steeper and may be totally eliminated in some areas where necessary such as at structures, storm drain outlets or other pinch points.

4) The north bank tributary channels will not include a re-grading of the creek invert although the E_p of the proposed condition will be evaluated. For Grande and Chiquito, the invert stabilization method will be as follows:

   a. Creek bed Grade Control Structures (GCS) at 200 to 400 foot spacing along the creek corridor will be included.

   b. These GCS's will be (attempt to be) located at points along the creek where proposed project grading impacts will already be disturbing the creek bed and banks.

   c. The GCS's will be constructed with soil cement, rip rap or other grade stabilization methods acceptable to LACDPW.

   d. The GCS will be at grade or below the existing grade and invert of the creek bed.

   e. The GCS will be designed to function as a drop structure in the event the creek bed slope flattens overtime.

5) North bank tributary channel top and toe elevation will be established based upon LACDPW standards:

   a. Toe down Q_{CAP} and n=0.025, maximum velocity and Toe from design manual.

   b. Top Q_{CAP} and n=0.085, maximum water surface and freeboard from design manual.

The above two HEC-RAS models will be evaluated for the following project conditions:

- proposed creek invert profile with below-grade GCS's and,

- the theoretical E_p slope invert profile (note the GCS's will become drop structures with equilibrium slope predicted in the E_p analysis)

Based upon the results of the above HEC-RAS modeling, the most conservative values for Top and Toe of the bank protection will be determined using LACDPW design manual criteria.

The overall north bank tributary creek design approach will allow the creek to naturally fluctuate between the stabilized existing condition and estimated equilibrium slope while providing suitable erosion and flood protection for public safety. Based upon the proposed design and use of LACDPW standards for bank protection top and toe these northerly channels would meet the minimal required maintenance design objective provided by LACDPW.

4. CHANNEL WIDTH AND DEPTH

Channel width and depth are calculated using an empirical approach using local reference reaches (Coleman et. al. 2005), verified by an erosion potential assessment to ensure that the design meets the appropriate target erosion potential within the 20 percent threshold.

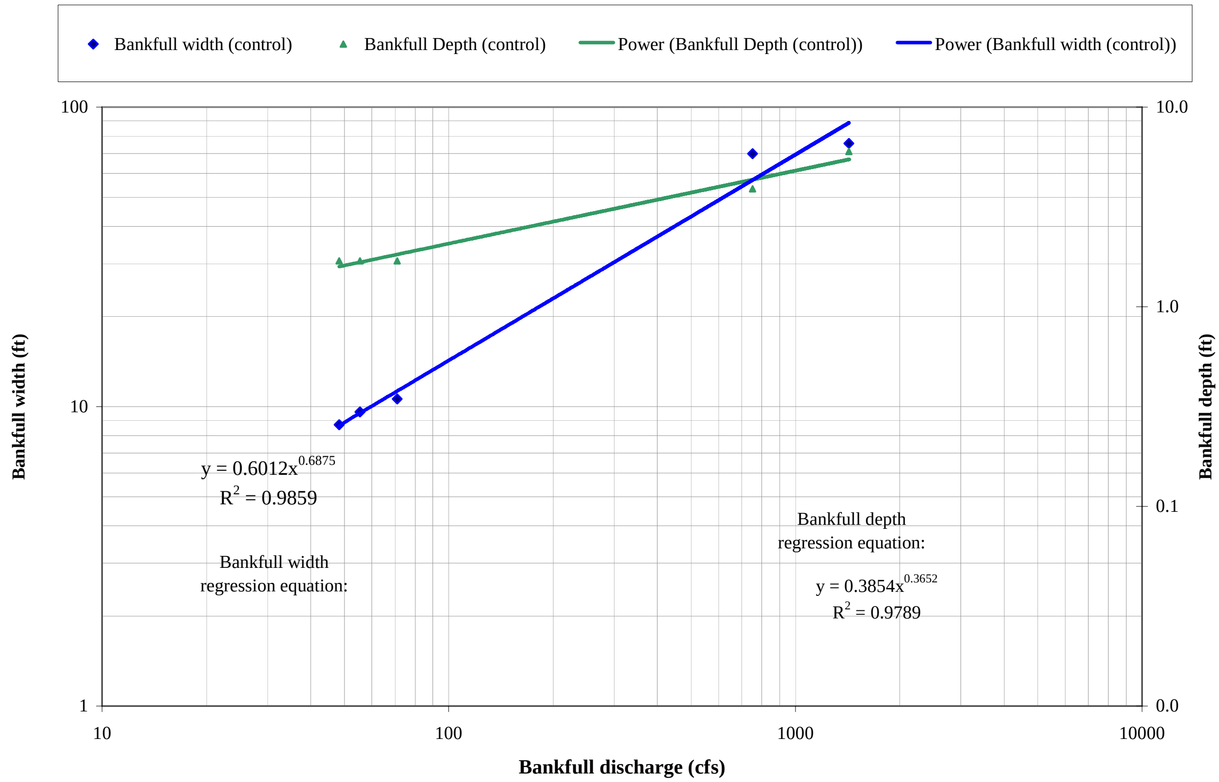
4.1 SOUTHERN CALIFORNIA FIELD REGRESSIONS

The Stormwater Monitoring Coalition (SMC) (Coleman et al., 2005) performed a geomorphic assessment of streams in disturbed and un-disturbed watersheds of Southern California. This study provides regional regressions between dominant discharge and channel geometry for Southern California stream channels, and identifies predictive relationships between changes in impervious cover and stream channel enlargement for use in stream management. Figure 4 shows predictive relationships between dominant discharge and bankfull width and depth based on the reference watersheds (undeveloped or very lightly developed) from the SMC study. We integrate the results from these channel systems with the estimates produced by other methods.

Table 3. Summary of Southern California Field Regressions

	Method 4 - SMC method
Inputs	Dominant discharge
Events Assessed	Bankfull discharge
Approach	Use regression equation from regional reference reaches to estimate channel width and depth
Output	Equilibrium width and depth of channel

Figure 4. Southern California Stream Morphology Relationships



Note: Plots derived from Coleman et al. (2005) Table 5.6. Data are only from control (undeveloped) sites

4.2 SELECTION OF A DESIGN CHANNEL WIDTH AND DEPTH

Following estimation of design parameters with the different methods, a proposed channel cross-section is selected which is likely to be most stable (falls between the high and low end of the estimates). The selected combinations of width, depth and slope are evaluated hydraulically to ensure that flow velocities are reasonable and unlikely to erode over the longer term.

5. STEP-POOL DESIGN

Where the slope estimation methods utilized predict that the proposed channel gradient will be considerably flatter than the existing gradient, drop structures and/or armored channels will be required to take up the elevation difference between the existing and proposed stable slopes. To maximize vegetation, aquatic, and wildlife habitat and maintain a natural channel appearance, a range of types of step-pool structures and armored riffles will be used to accommodate the drops in channel elevation. Construction of these structures will likely include large boulders, soil cement or concrete and will mimic natural step-pool function and morphology (as identified in reference reaches) in appearance and hydraulic function.

5.1 SELECTION OF MULTIPLE SMALL STEPS OR FEWER LARGE STEPS

Two approaches have been taken to controlling channel grade, to be used in different settings. Where the existing stream course and valley is going to be significantly altered by mass grading we consolidate drops into a smaller number of larger drops, to allow for greater lengths of non-armored channel between drops. Where the goal is preservation of existing channel habitat and little mass grading is proposed for the channel and floodplain area we use larger numbers of smaller drops (approx. height 3 feet) to control grade. Selection of these approaches is made based on the habitat value of the existing creek corridor and the infrastructure and mass grading needs of the surrounding development.

5.2 DESIGN PROCEDURE

The approximate initial step-pool dimensions are determined using the approach of Thomas et. al. (2000). Once the approximate structure dimensions are determined, this initial dimension is then tested using HEC-RAS to optimize the height of the step, gradient of the ramp, depth and width of pool and elevation of the apron/tail water. HEC-RAS flow estimates are also used to develop flow discharge per unit width for sizing rock to be used in the grade control structures or for bank protection. The detailed analysis and final design for the step-pool structures will be described in final design technical memorandums.

5.3 GRADE CONTROL CONCEPTS

The types of step-pool structures and armored riffles that would be used to accommodate drops in channel elevation are described below and illustrated in Attachment A.

5.3.1 Grouted Sloping Boulder (GSB) Drop

Boulders, typically 24-inch minimum in all directions, would be placed on the face of the grade control structure, the crest, the lower part of the side slopes, and the stilling basin. Twelve inches of grout would be placed at the bottom 30-50% depth of the boulders to lock them together. Typical vertical drop heights for this type of grade control structure may be greater than 3 feet and are proposed at up to 15 vertical feet. The structure length and width varies depending on the design flow; typical structure dimensions may be 100 feet long by 60 feet wide. Planted riprap would be placed along the approach, in the upper voids of the boulders, along the upper banks, and downstream of the stilling basin (lay down toe). Seepage control would consist of a metal or vinyl sheet pile across the width of the structure and weep drains that daylight through the grouted boulders.

5.3.2 Soil Cement Grade Control Structure

On-site sandy soils will be combined with adequate cement to form a soil cement mixture that when placed mimics the sandstone outcrops in the area. Facings and lateral protection will be built by constructing the soil cement slope protection in successive horizontal layers (6-10 inches thick). Facing slopes can be steeper than GSB Drops with the steepest recommendation at nearly 0.5:1 (H:V); constructed by setting back subsequent lifts. Typical vertical drop heights for this type of grade control structure may be greater than 3 feet and are proposed at up to 15 vertical feet. The structures in some locations will be combined to make up vertical grades exceeding 15 feet which is acceptable given adequate geotechnical and structural design. The structure length and width varies depending on the design flow; typical structure dimensions may be 80 feet long by 80 feet wide. Planted riprap would be placed along the approach, in the approach at the crest, along the upper banks, and downstream of the stilling basin (lay down toe). Soil cement would be mixed on-site, placed, compacted, finished and cured resulting in a strong durable, erosion-resistant material with low permeability. Seepage control would consist of a metal or vinyl sheet pile across the width of the structure and weep drains that daylight through the soil-cement lifts.

5.3.3 Sculpted Concrete Drop Structure

Colored, poured and shaped concrete will be molded to form an aesthetic modification to the grouted sloping boulder style of drop. Design of for these drops will be conducted individually but similar to the GSB Drop. Construction is typically conducted with a single monolithic full-depth pour or using a two pour system over steel reinforcement then contoured and textured to finish. Planting wells may be considered to help revegetate and conceal the structure. Facing slopes are roughly similar to GSB Drops with the steepest recommendation at nearly 3:1 (H:V). Typical vertical drop heights for this type of grade control structure may be greater than 3 feet and are proposed at up to 15 vertical feet. The structures in some locations will be combined to make up vertical grades exceeding 15 feet which is acceptable given adequate geotechnical and structural design. The structure length and width varies depending on the design flow; typical structure dimensions may be 100 feet long by 80 feet wide. Planted riprap would be placed along the approach, in the approach at the crest, along the upper banks, and downstream of the stilling basin (lay down toe). Seepage control, where necessary, could consist of a metal or vinyl sheet pile across the width of the structure and weep drains that daylight through the poured grout mixture.

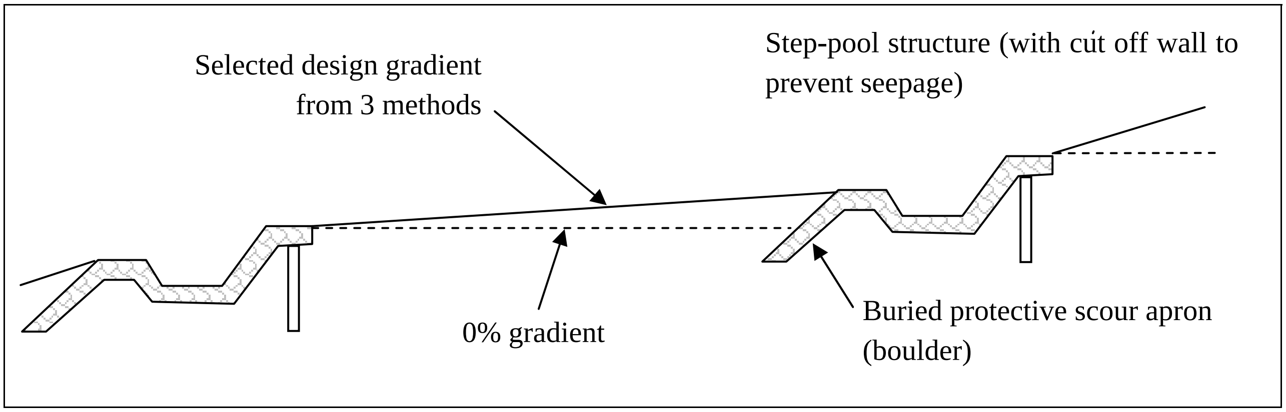
5.3.4 Non-Grouted Boulder Step-Pool

Boulders, comprised of various sizes between 24-inch and 36-inch minimum in all directions, would be placed on the face of the step-pool structure, the crest, the lower part of the side slopes, and pool. The sub-base of the structure will be adequately designed using a mixture of compacted soil and riprap. The boulders would be individually placed and chinked to lock them together. Plants will also be used to prevent boulders from dislodging. The crest boulders would be placed on top of a metal or vinyl sheet pile wall and grouted to the buried check wall to form the crest. The check wall would extend to the width of the floodplain corridor and will be notched at the step-pool structure. While the structure will be designed to be stable at Qcap, the capacity of the non-grouted boulder step-pool will be designed for less than Qcap and have typical dimensions of roughly 50 feet by 50 feet, with excess water passing onto the floodplain as dispersed flow. Planted riprap would be placed along the approach, in the upper voids of the boulders, along the upper banks, and downstream of the pool.

5.3.5 Grade Control Scour Apron

Grade control structures would include a buried toe scour apron made of appropriately sized rock on the downstream end of the step-pool structure to accommodate the most conservative slope assumptions (i.e., assume that a 0% slope develops) to insure that the structures will still have integrity and channel downcutting will be prevented (see Figure 5 below). The designs will also include intermittent buried rock sills across the floodplain to protect from erosion or outflanking of the step pools. For a typical design of 1% channel gradient and structures every 100 feet, the worst case scenario (adjustment of the channel to zero gradient) would be 12 inches of toe erosion on each structure.

Figure 5. Conceptual Sketch of Step-pool Structures Showing Relationship Between Design Gradient and Lowest Predicted Gradient



6. CHANNEL MIGRATION

Where feasible, many reaches of channel that will be either restored or designed for Newhall Ranch will have some degree of natural geomorphic dynamic function, including a limited ability to meander and laterally migrate within proscribed limits. A design standard has been developed to assess and constrain the potential for the constructed or restored channels to migrate laterally into the toe of the valley side, without putting adjacent development at risk from bank erosion. The method is based on the observation that for given geomorphic settings stream channels have a maximum sinuosity above which they avulse to a straighter course. By forcing the channel to occupy the middle of the floodplain at set spacings we can prevent the outside of a meander bend from reaching the edge of the floodplain (and eroding the corridor banks). The method uses predictions of the upper sinuosity and calculations of the location of a meander bend in response to a given sinuosity.

6.1 PREDICTING CHANNEL MIGRATION

We have integrated the variables which control migration into an analytic model of meandering to calculate the maximum appropriate spacing between fixed channel control points to avoid a channel migrating into the edge of a floodplain of given width.

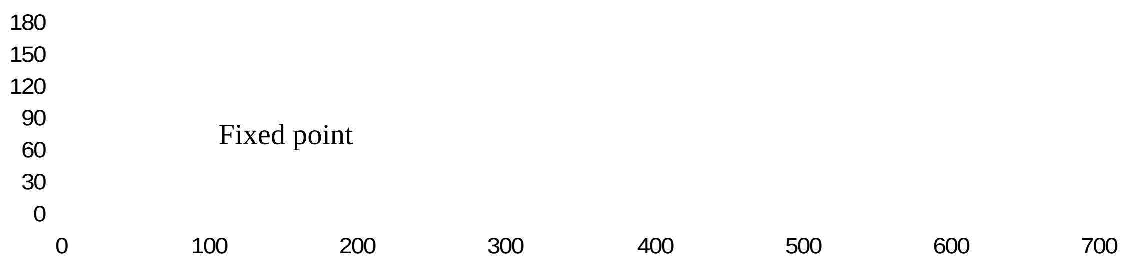
6.1.1 Maximum Safe Spacing Allowed Between Fixed Points to Avoid Migration into the Floodplain Edge

Meanders are often modeled as sine generated curves (see for example Dunne and Leopold, 1978). A series of sine generated curves were created with different amplitudes (corresponding to the range of valley floodplain widths proposed for Newhall Ranch). Sinuosity was set at 1.5, which is the highest sinuosity observed on any stream in the vicinity of Newhall Ranch (found on a reach of Salt Canyon with a valley floor of 1.3% and a watershed area of 8 square miles).

Figure 6. Reference Reach in Salt Canyon Showing Typical Sinuosity and Corridor Width (sinuosity of 1.3)

An example plot from the analytical model is shown below, for a corridor width of 180 feet: With a 180 foot wide corridor, the fixed points should be spaced within 180 feet of each other to such that if the channel migrates to the floodplain edge, it will form a cut-off and move back towards the centerline.

Figure 7. Example Model Output



This relationship was used to determine the appropriate spacing for structures for various sinuosity and corridor width combinations. For a sinuosity of 1.5 (a conservative upper value) a fixed point is required once every floodplain width.

6.2 PROJECT APPLICATION

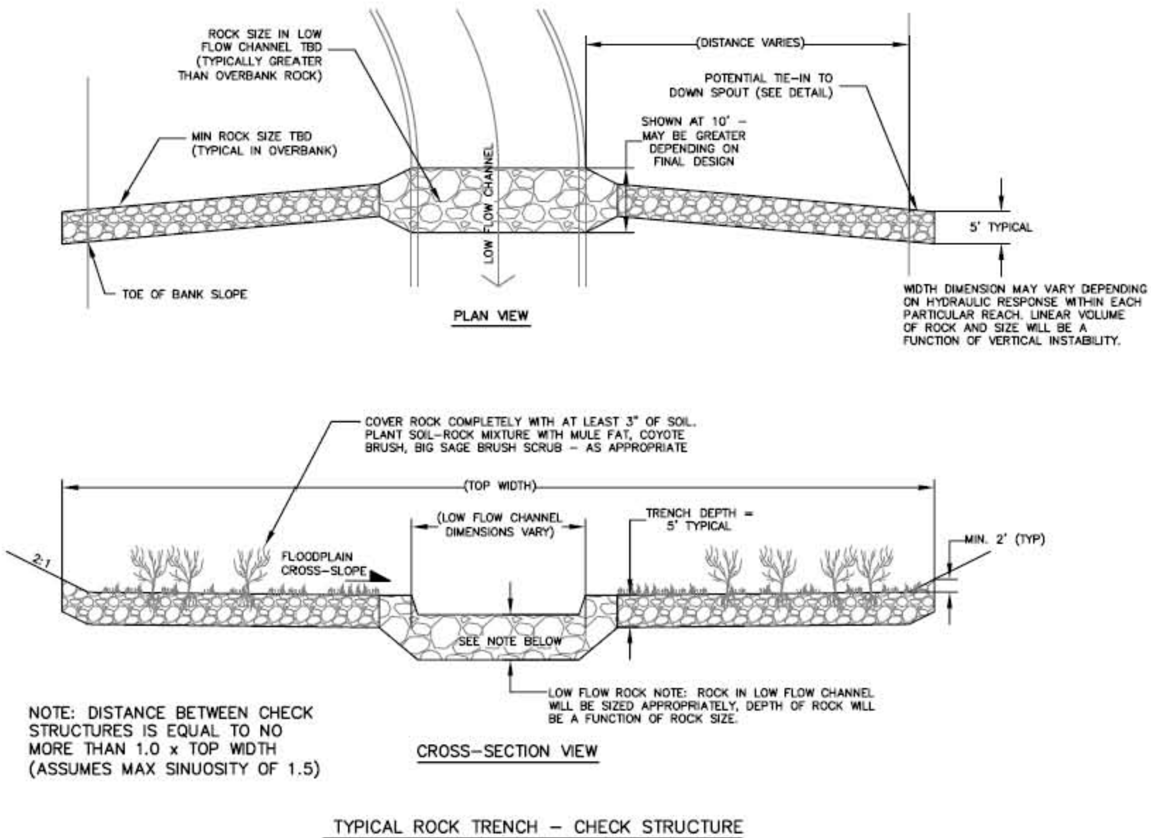
In most locations along the canyons where small drop structures are proposed, the proposed GCS spacing is less than the predicted minimum required spacing, and the risk of channel migration is low. Where the floodplain narrows (near channel culverts and location where detention basins confine the floodplain) we propose the use of floodplain toe armor (rock or comparable protection).

Several portions of the canyons have longer reaches without step-pool structures, where channel migration could reach the floodplain edge if unconstrained. We will use one of two approaches in these cases:

1. Construct channel training structures that force the channel to occupy the middle of the valley floor. Structures will be located with spacing equal to one floodplain floor width. Training structures will be buried rock-filled trenches as shown in Figure 8.

2. Construct slope toe protection along the floodplain edge (see Figure 9).

Figure 8. Typical Detail for Channel Training Structure



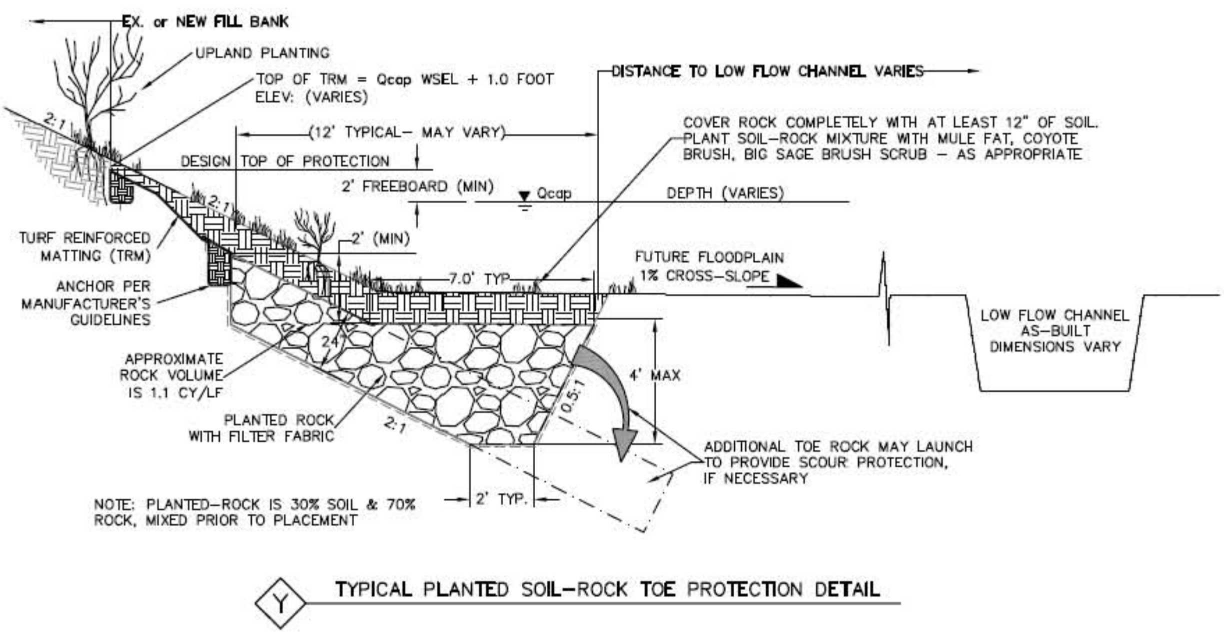
7. BANK PROTECTION

The canyon stabilization plan is based on the establishment of stable stream slopes which will reduce velocities and thus erosion potential. With the stream profile controlled, bank erosion can be mitigated and future impacts due to development minimized.

7.1 TOE PROTECTION ALTERNATIVES

The selected bank improvements are designed to minimize environmental impacts, mitigate impacts, and preserve the character of the existing canyons where possible. Since grade stabilization will minimize streambed lowering, will reduce velocities and shear stresses, and will improve hydraulic stability, the potential for bank erosion and undercutting will be reduced. It is anticipated that the improved hydraulic response of the channel will result in a reduction in the level of bank protection required and allow selection of a lower-impact toe protection method (see **Error! Reference source not found.**9 below).

Figure 9. Typical Cross-Section Detail for Planted Soil-Rock Toe Protection



Toe protection will be located at newly constructed banks, areas where infrastructure, homes, structures, are proposed, and areas where significant lateral channel movement is expected. Toe protection will be designed as a permanent, continuous treatment that will protect from cut-bank scalloping, under-cutting, or bank failure caused by the lateral migration of the low flow channel or localized scour. Rock placement along the toe of slope will be wide enough to provide maximum protection from migration of the low flow channel and is designed to launch as needed to protect the bank from localized scour.

The following Table provides a description of the various permanent bank and toe protection alternatives and establishes the application criteria for their use.

Table 4. Bank Protection Alternatives and Application Criteria

Permanent Bank and Toe Protection (Longitudinal)	Min Side Slope (H:V)	Permissible Shear Stress (lbs/SF)	Permissible Velocity* (fps)	Hydraulic Requirement (Moisture regime)
VEGETATION				Low to Moderate
Vegetation – Short Native Grass	3:1	0.7 – 0.95	3.0	mesic/xeric
Vegetation – Long Native Grass	3:1	1.2 – 1.7	4.0	mesic/xeric
Vegetation - Shrubs	2:1	1.5 – 3.0	5.0 - 7.0	mesic/xeric
VEGETATION WITH REINFORCEMENT				
Turf Reinforced Matting	2:1	3.0 - 4.5	7.0	Low
ROCK WITH VEGETATION				
Planted-Rock 6-in D50	2:1	2.5	5.0 - 7.0	Varies - Plant Dependent
Planted-Rock 9-in D50	2:1	3.8	7.0 - 11.0	Varies - Plant Dependent
Planted-Rock 12-in D50	2:1	5.1	10.0 - 13.0	Varies - Plant Dependent
Planted-Rock 18-in D50	2:1	7.6	12.0 - 16.0	Varies - Plant Dependent
Placed Rock / Boulders 24-in +	2:1	7.6 – 10.0	15+	Varies - Plant Dependent
Stacked Planted Boulders	1.5:1	8.0 – 11.0	15+	Varies - Plant Dependent
STRUCTURAL				Plant Dependent
Soil Cement	0.5:1	11.0 +	15+	N/A
Cribwalls, Vegetated	0:1	12.0 +	15+	Varies - Plant Dependent
Stacked Grouted Boulders	0.5:1	12 +	15+	N/A

*Velocities shown are guidelines only – refer to Chart C-10 in Appendix C of the LACDPW Sedimentation Manual

7.2 BANK PROTECTION SELECTION PROCEDURE

Results from proposed conditions hydraulic analysis will be used to determine the shear stress and velocity along the subject reach. Where shear stress is determined to exceed the natural resistance of the channel banks, bank protection will be required. Bank protection will be selected by comparing the predicted bank erosion shear with the bank protection application criteria in Table 4. We will use the following steps to determine what type of bank protection is required:

a. Toe protection shall be, at a minimum, assessed for the following channel conditions:

- At bends,
- In areas of fill,
- At contractions and expansions,
- Along maintenance roads,
- Where the low flow channel is adjacent to the corridor edge, and
- Where corridor side slopes are steeper than 2:1 (Note: At this stage all side slopes are assumed to be 2:1 or flatter).

b. Toe protection shall be required to mitigate for hydraulic conditions that do not meet the established hydraulic criteria;

1. Typical Cross-Section Detail for Planted Soil-Rock Toe Protection (Figure 9) shall be used to design toe protection based on channel geometry and hydraulic characteristics.
2. Use the application criteria to estimate rock size based on permissible shear stress (Table 4) and permissible velocity using Chart C-10 of Appendix C of the LA County sedimentation manual.

c. Toe protection shall be required downstream of storm outfalls or down drains and continue to the next downstream grade control structure;

d. Toe protection shall not be required in natural channels or modified channels that provide a succession of grade control or check structures that will prevent the lateral movement of the low flow channel into the banks – based on a geomorphic assessment of the potential sinuosity of the stable channel (see section 7);

e. Toe protection shall not be required when the Qcap floodplain does not intersect above the toe of the channel bank.

f. If hydraulic criteria for the proposed biotechnical slope protection measures are not met, revise channel characteristics, grade control selection or select a structural bank protection method using grouted stacked boulders, soil cement, riprap lined channel or other LA County bank protection method (LACFCD 1982).

8. HYDRAULIC CRITERIA

This section describes hydraulic criteria for the design of natural channels utilizing grade control alternatives described in subsequent sections to achieve stable channel slope. Once the initial channel design and step-pool design is completed, the channel configuration is evaluated for stability and hydraulic performance using HEC-RAS. HEC-RAS is used to assess the channel, floodplain and steps at a range of flow conditions to determine:

- Final design of step-pools
- Rock sizing
- Compliance with LACDPW freeboard requirements (3 feet during Qcap)
- Compliance with established hydraulic criteria
- Sufficient dissipation of energy by step structures during high flow events
- Non-erosive velocities on floodplain and along constructed slopes

Initially, individual step-pools will be modeled through a range of flows to optimize hydraulic design. Sequences of steps are then added to the model to simulate proposed conditions throughout the project reach.

8.1 HYDRAULIC ANALYSIS

The design procedure currently uses a one-dimensional hydraulic model (HEC-RAS) to evaluate hydraulic criteria. The model is used to characterize existing conditions and to examine the function and capacity for grade control to meet the defined hydraulic criteria for future channel conditions (post-project).

A model of the existing channel conditions is used to establish the baseline hydraulic performance. The Existing Conditions model must adequately represent existing (pre-project) topographic and hydrologic conditions.

Use the Existing Conditions model to:

- Determine the hydraulic response of the existing conditions capital flood (existing Q_{cap}) and 25% of the capital flood existing ($0.25Q_{cap}$).
- Determine the hydraulic response of the proposed conditions capital flood (proposed Q_{cap}) and 25% of the capital flood (proposed $0.25Q_{cap}$).
- Identify extent of the existing 100-year floodplain and elevation of the flood profile.

The Existing Conditions model is then modified to reflect and test channel design alternatives for their ability to satisfy the hydraulic design criteria. Simulation scenarios are summarized in Table 5.

- Revise the existing conditions model for at least two representative channel reaches to test the various grade control options (see Section 2).
- Estimate dimensions and spacing for grade control structures
- If applicable, estimate dimensions of low-flow channel to (1) contain proposed conditions Q_2 flows in low-flow channel, (2) allow floodplain activation during flows > Q_2 in compound channel section.
- Develop Proposed Conditions model using grade control dimensions and spacing and design channel section estimated above.
- Run Proposed Conditions model for Q_2 , $0.25Q_{cap}$, and Q_{cap}.
- Check model results against hydraulic criteria in Table 4.

Table 5. Model Simulation Scenarios

Simulation	Land Use	Comments
Existing Conditions	Current	Existing channel geometry with Existing Conditions Flow rates
Existing Conditions (Manning's "n" Sensitivity Test)	Current	Existing channel geometry with Existing Conditions Flow rates. Increased roughness to account for flow resistance due to sediment transport of the bed load and floodplain resistance
No channel Improvements	Post-Project	Existing channel geometry with Proposed Conditions Flow rates
Conceptual Channel Improvements	Post-Project	Proposed conditions channel geometry for 2 typical reaches (A and B). Grade Control Structures located within the two reaches
Preliminary Channel Improvements	Post-Project	Proposed conditions channel geometry with selected Grade Control structures.

9. MONITORING AND MAINTENANCE OF THE CHANNEL

A monitoring and maintenance plan is being prepared as part of the project EIR/EIS, and will be attached to this Basis of Design document on completion.

10. ACCESS REQUIREMENTS

The property ownership underlying the channel will be either by HOA, environmental stewardship organization such as Center for Natural Land Management or a quasi-governmental organization such as a Geologic Hazard Abatement District (GHAD). Access to the facilities that may need maintenance or observation will be provided through easements granted to Flood Control. Newhall Land has had several discussions with Flood Maintenance as to the type and need for maintenance access to this type of channel design. Details will be shown as part of the project-level analyses and plans.

11. REFERENCES

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ATTACHMENTS