3. STREAM ASSESSMENT METHOD

3.1 DESCRIPTION OF ASSESSMENT METHOD

The assessment methodology was subdivided into five elements: 1) Problem area and reach characterization, 2) geomorphic assessment, 3) hydrologic modeling, 4) stability assessment, and 5) effectiveness evaluation of potential control measures.

Problem area and reach characterization describes features of the watershed and stream channels necessary to understand the nature and extent of the problem and to explain existing conditions. Historical aerial photography, soils and geologic maps, channel maintenance records, infrastructure data and historical surveys were used to distinguish between urbanizing impacts and impacts caused by past land use practices.

The geomorphic assessment describes the geologic and geomorphic characteristics of the stream network, the dominant physical processes that seem to be controlling stream attributes and erosion, and the extent and modes of failure for observed eroding channel banks and beds. Field crews recorded reach-wide observations on streambed and bank erosion, collected location specific data at multiple cross sections, and then assigned each cross section a rank of *stable, low, medium or high* observed condition of erosion, or likelihood of erosion in the near future. Several factors affecting channel bank and bed stability were combined with the extent, age, and magnitude of existing erosion to designate an appropriate erosion ranking.

Hydrologic continuous simulation models of the pre-urban[1], existing, and future (year 2020) land use conditions were developed using the U.S. Army Corps of Engineers' Hydrologic Engineering Center - Hydrologic Modeling System (HEC-HMS). The models were calibrated using two to four years of measured flow data. The calibrated models were run using 50+ years

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[1] The pre-urban land use condition was modeled to enable comparison of stable stream segments to unstable segments under existing land use and validate the assessment methodology (see Section 3.3).

of rainfall records, which produced a time series of hourly stream flows to analyze changes in flow duration, runoff volume, and frequency between land use scenarios.

The stability assessment looks at the balance among flow energy and channel resilience that exists in a stable stream. An index representing the total effective work done, W, (i.e., hydraulic force applied) to the channel boundary is derived that predicts the probability of channel adjustment given watershed and stream hydrologic and geomorphic variables. The effective work index under urbanized conditions is compared to the index under pre-urban conditions. The comparison, expressed as a ratio, is defined as the Erosion Potential (Ep) following research by MacRae (1992, 1996).

An empirical relationship between Ep and the observed erosion classification of stream segments was derived and used to make informed management decisions. A “threshold of adjustment” is considered that distinguishes between stable and unstable conditions. The Ep and the threshold of adjustment are used to set management criteria and evaluate the effectiveness of proposed solutions (using the method developed by MacRae, 1993).

3.2 SELECTION OF TEST WATERSHEDS

Provision C.3.f. of the NPDES permit requires Co-permittees to develop an HMP that applies to all of the Santa Clara Basin watersheds under the jurisdiction of the SCVURPPP Co-permittees. A key question raised early in the HMP development was whether a single standard, management criteria and threshold could be used for all watersheds in the Basin for uniformity and ease of implementation or whether the watersheds are different enough to warrant site- or area-specific standards, as allowed by Provision C.3.f.v.

According to geomorphic theory, watersheds and streams with different climate, physiography, soils and vegetation could potentially have different resilience and thresholds of adjustment and thus could require different standards. On the other hand, if the assessment methodology is parameterized effectively, incorporating the relevant physical processes, the method could account for these differences and lead to uniform results.

Based on the watershed and stream assessment work completed for this HMP Report, the consultant team concluded that the Basin can be sub-divided into three regions with similar characteristics: the Coyote Creek watershed, the Guadalupe River watershed, and the western watersheds (San Tomas Aquino Creek to San Francisquito Creek[2]). Subwatersheds were identified to represent these three watersheds. The Lower Silver – Thompson Creek subwatershed was selected to represent the eastern Coyote Creek region and the Ross Creek subwatershed was selected to represent the Guadalupe River region. San Tomas Aquino Creek (also referred to as San Tomas Creek) was chosen to represent the characteristics of the western watersheds. Figure 3-1 presents a map showing the Basin and the location of the three test subwatersheds.

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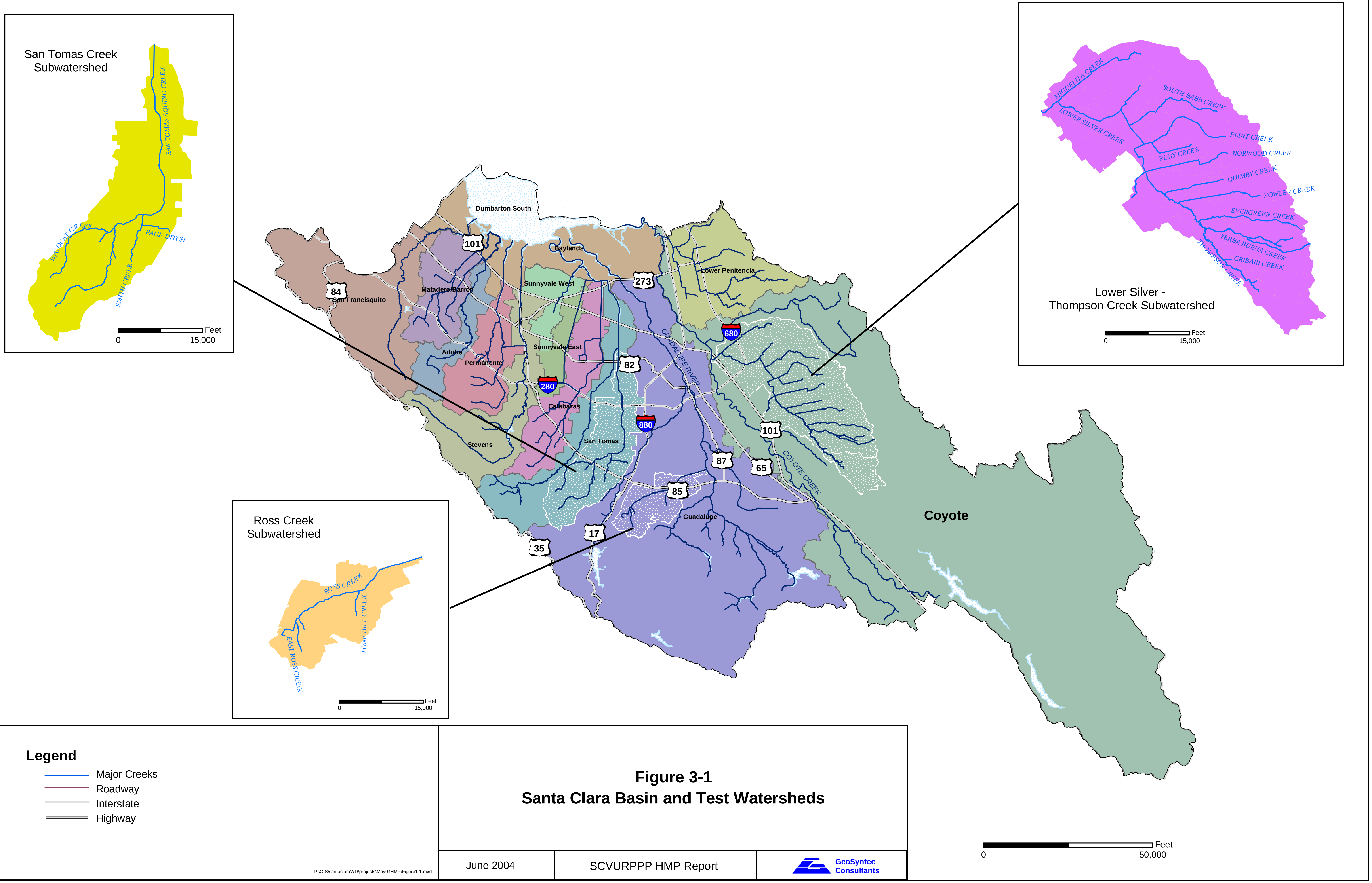
[2] Approximately two-thirds of the San Francisquito Creek watershed is located in San Mateo County. The San Mateo Countywide Stormwater Pollution Prevention Program (STOPPP) has requirements to complete an HMP in its NPDES permit; however, the timeframe for implementation is different. The draft HMP for STOPPP is due to the Regional Board on November 15, 2004. SCVURPPP intends to collaborate with STOPPP such that a coordinated plan for San Francisquito Creek is developed.



Legend

- Major Creeks
- Roadway
- Interstate
- Highway

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Figure 3-1
Santa Clara Basin and Test Watersheds

June 2004	SCVURPPP HMP Report	GeoSyntec Consultants

The first test subwatershed, Lower Silver/Thompson Creek (GeoSyntec Consultants, July 2003), was used primarily to develop, test, and verify the assessment method itself. For example, “can we correctly predict existing erosion and deposition?” “How successfully can we define erosion thresholds?” The second and third test subwatersheds, Ross Creek and San Tomas Creek, were used to verify that the method works in watersheds with different characteristics and answer the following question:

- Are the results for Thompson Creek, Ross Creek, and San Tomas Creek significantly different enough to warrant separate hydromodification standards, criteria, and threshold?

The three test subwatersheds were selected for the following reasons:

1. Each subwatershed represents a distinct hydro-geomorphic region of the Basin.
2. The subwatersheds are of a size appropriate for the testing methodology (approximately 20 to 40 square miles).
3. Each subwatershed has a stream gage(s) where data have been and are being collected that were used to help calibrate the hydrologic model.
4. The subwatersheds have undergone significant development in the past 20 to 40 years, with some additional growth planned for the future. Thompson Creek underwent significant development from the late 1970’s, while development in Ross Creek and San Tomas Creek began around the late 1950’s.
5. The streams are earthened channels and show signs of hydromodification type impacts due to urbanization. Other effects, such as dams and reservoirs, gravel mining were not present in these watersheds.

3.3 APPLICATION OF THE ASSESSMENT METHODOLOGY

This chapter summarizes the application of the assessment method to the Thompson Creek, Ross Creek, and San Tomas Creek subwatersheds.

Geomorphic Assessment

A field geomorphic assessment was completed for the subwatersheds of Thompson, Ross, and San Tomas Creeks. Conducting a geomorphic assessment is a critical step toward understanding the hydrologic and geomorphic processes that influence channel stability within an urbanizing watershed. The historic assessment and geomorphic field work conducted for this study provide the foundation for evaluating how past hydrologic conditions have changed, how modified flow pathways have affected channel form and stability, and what this information means in terms of how the system might be managed to create an ultimately stable channel.

The geomorphic assessment complements and supplements information provided by hydrologic models of storm runoff and stability assessment, and helps in the interpretation of what the models mean in different stream systems.

The geomorphic assessment was conducted on two different scales, with the identification of both geomorphic reaches as well as hydrographic segments. Creeks vary longitudinally—that is, from upstream to downstream, both with respect to channel bed and bank properties and with respect to the magnitude and duration of flows that act upon them. The intrinsic properties of bed and banks plus the flows acting upon them need to be considered when developing a method for predicting how future flows will affect the creek.

The consultant team distinguished geomorphic reaches that characterize each creek based on the longitudinal variation of bed and bank conditions. Within a given reach, broadly similar influences (whether vegetation, geology, topography, level of upstream development, etc. or some combination therein) affect channel form and processes in a similar manner.

Hydrographic segments differ from geomorphic reaches in that they define a creek section based on significant flow additions, whether it is from tributaries, diversion structures, and/or stormwater outfalls rather than physical characteristics of the channel. Cross-sections located within a common hydrographic segment are characterized as having similar discharges. The segmentation reflects important differences in channel-forming flows.

The geomorphic field work consisted of taking a set of qualitative and quantitative measurements at multiple cross-sections along Thompson, Ross, and San Tomas Creeks. Cross-sections were selected to represent typical problem sites found within the subwatersheds. It was also a goal to compare unstable sites with ones appearing to be stable. Therefore, cross-sections were also located at non-problem sites that did not experience incision or excessive erosion for use in the stability assessment model.

The problems observed reflected both site-specific conditions as well as larger-scale watershed factors. The field program provided the data to characterize both small- and larger-scale hydrologic and geomorphic factors causing creek problems.

Based on the results of the geomorphic assessment, hydromodification has clearly impacted streams in the Santa Clara Basin[3]. Field observations have found streambed incision from 2 to 20 feet deep depending on stream location. Bank retreat and channel widening was also observed. In some locations, bank failure and slough off had occurred during larger storms because of over-steepened and over-tall banks. Hydromodification impacts are observed in some earthen-engineered channels in the three test subwatersheds as well as in natural streams.

Hydrologic Modeling

This section describes the hydrologic modeling of the Thompson Creek, Ross Creek, and San Tomas Creek subwatersheds. Modeling was conducted as part of the hydromodification assessment as well as the technical analyses conducted during the planning process (see Chapter 4).

Creek flows were modeled under pre-urban (i.e., before large scale development of the subwatershed)[4], existing, and future land use conditions. The watershed models convert rainfall input sequences to estimated stream flow rates at various selected points throughout the project

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[3] The complete set of results for the Thompson Creek cross-sections is presented in *Hydromodification Management Plan, Draft Interim Report, Assessment of the Lower Silver–Thompson Creek Subwatershed.* Prepared by GeoSyntec Consultants, Inc. for SCVURPPP. Submitted to the RWQCB in July 2003.

[4] The pre-urban land use condition was modeled to enable comparison of stable stream segments to unstable segments under existing land use and validate the assessment methodology. Predictions for stream instability and erosion occurring between the pre-urban and existing scenarios were compared to observed locations of erosion.

watersheds. The model rainfall input consisted of simulated "design storms" and continuous rainfall records to conduct single event-based and continuous simulations, respectively. Design storms were developed for various rainfall magnitudes, such as the 2-, 10-, or 100- year rainstorms. The design storm approach was applied to the Thompson Creek subwatershed as a way to compare modeling techniques and their effectiveness at addressing and managing hydromodification impacts on stream channels. Design storm modeling was not necessary for Ross Creek or San Tomas Creek subwatersheds.

Within event-based and continuous simulations, the model incorporates information about the watershed characteristics (topography, soils, vegetation, land use, urbanization, etc.) to estimate how much rainfall is held in the watershed ("losses", including infiltration to the soil and capture on vegetation or in shallow depressions, etc.), and how much precipitation results in surface runoff, eventually reaching stream channels.

The consultant team chose to model the Thompson, Ross, and San Tomas Creek watersheds using the U.S. Army Corps of Engineers' Hydrologic Engineering Center - Hydrologic Modeling System (HEC-HMS) rainfall-runoff model. The U.S. Army Corps of Engineers developed HEC-HMS to supersede the HEC-1 Flood Hydrograph Package. Unlike the single event-based HEC-1, HEC-HMS allows continuous hydrograph simulation over long periods of time in addition to event-based analysis.

Event-based modeling is useful because it provides a simple method for comparing hydrograph results under different land use conditions for statistically relevant design storms. In addition, event-based modeling is a convenient and commonly accepted approach for evaluating flood risk and design alternatives. Continuous modeling, however, allows for continuous accounting of soil moisture and infiltration and other losses for an extended time period. Therefore, continuous modeling is preferable to event-based modeling when trying to identify the hydromodification effects of development on small, frequent erosive flows and to evaluate their impacts on stream stability.

The modeling approach generally followed methods and procedures for HEC-1 modeling outlined in Santa Clara Valley Water District's *Hydrology Procedure*s (SCVWD, 1998). A previous Thompson Creek hydrology study conducted by Nolte Associates (2000) and a Ross Creek study described in SCVWD's *Hydrology Procedures* also provided background information and estimated flow peaks for model comparison.

Existing hydrologic conditions were modeled using detailed soils and land use GIS data from the SCVWD. The land use data were then modified to model hydrologic conditions for future and past (pre-urbanized) conditions. For the pre-urban scenario, the consultant team reviewed County of Santa Clara aerial photographs from the 1950s and 1960s and USGS topographic maps of the region to characterize the pre-urbanized land use conditions in the subwatersheds. These sources provided a representation of the pre-urban distribution of developed, agricultural, and woodland and grassland areas for each subwatershed, which was then converted to model parameters. For future conditions, the percentage of impervious land for each subwatershed under current conditions was increased based on future build-out information from city and county general plans. For details on the method of estimating future imperviousness, see Mattern & Associates, 2003.

HEC-HMS was used to predict stream flows at selected locations within the study areas. The models were calibrated and verified using two to four years of measured stream flow data. Continuous simulations were run for the 50-year period of rainfall record to analyze changes in flow duration, runoff volume, and frequency between pre-urban, existing, and future (year 2020) land use conditions.

Results of the hydrologic modeling are presented below. Due to the large amount of data generated by the model for each land use scenario (50 years of hour data at multiple locations), summary results of select locations are presented to demonstrate representative model results. The reader can refer to Appendix I to find more details regarding model results. The hydrologic model results are described in terms of *frequency* of ALL storm events (not just partial or annual series) and *duration* of flows.

Storm Magnitude: Table 3-1 presents a brief summary of the predicted changes in peak flow magnitude for two locations in Thompson Creek and two locations in Ross Creek. In the upper portion of Thompson Creek upstream from the confluence with Yerba Buena Creek (J-5), the 10-year peak flow increases from 520 cfs under pre-urban conditions to 620 cfs under existing and 730 cfs under future conditions (a 20% and 40% increase between pre-urban and existing and future conditions, respectively). The 2-year peak flow increases from 100 cfs to 190 cfs under existing and 270 cfs under future conditions (a 90% and 170% increase between pre-urban, and existing and future conditions, respectively). Similar results are provided for the lower portion of Thompson Creek, near Quimby Road (J-12). The magnitude of change predicted for Ross Creek is much greater than that predicted for Thompson Creek; examples are provided for locations J-1 (downstream) and J-5 (upstream).

Table 3-1 – Summary of Changes in Peak Flow Magnitude (cfs)

	Pre-Urban		Existing		Future		Percent Change Pre-urban vs. Existing	
Location	**2 year**	**10 year**	**2 year**	**10 year**	**2 year**	**10 year**	**2 year**	**10 year**
TC J-5	100	520	190	620	270	730	90	20
TC J-12	520	1500	1300	2250	1500	2500	150	50
RC J-1	240	500	1100	1480	1300	1750	358	196
RC J-5	150	250	390	580	410	610	160	132

Notes: 10-year return periods based on “annual” frequency distributions of the continuous simulation results.

Storm Frequency: Table 3-2 summarizes the change in frequency of occurrence for the 2-year and 10-year peak flows. Consider the upper reach of Thompson Creek (J-5) for example; the 10-year peak flow for the pre-urban condition (~520 cfs) occurs approximately every 6 years under existing conditions and every 5 years under future conditions. The 2-year peak flow under pre-urban conditions (~100 cfs) now occurs about once every 18 and 16 months under existing and future conditions, respectively. Similar results are also provided for the lower portion of Thompson Creek (J-12).

The Ross Creek subwatershed, similar to Thompson Creek, is largely built-out in the lower reaches. The pre-urban 10-year peak flows for both the downstream (J-1) and upstream (J-5) ends are now expected to occur several times a year. The pre-urban 2-year peak flows are also predicted to occur several times a year under existing and future conditions.

Table 3-2 – Summary of Changes in Peak Flow Frequency of Occurrence (years)

Location	**Pre-Urban**		**Existing**	**Future**
	Return Period (Years)	Flow (cfs)	Return Period (Years)	Return Period (Years)
TC J-5	10	520	6	5
	2	100	1.5	1.3
TC J-12	10	1500	2.5	2
	2	520	0.6	0.4
RC J-1	10	500	0.28	0.2
	2	240	0.1	0.1
RC J-5	10	250	0.28	0.25
	2	150	0.5	0.4

Notes: 10-year return period based on “annual” frequency distribution
2-year return period based on “partial duration” frequency distribution

One of the more dramatic changes is the frequency of small storm events less than the 2-year peak flow. For example, under pre-urban conditions, small runoff events occur about two to three times each year on average. Under both existing and future conditions, runoff events now occur almost every time there is a rain event. Furthermore, the magnitude of the events that occur two to three times a year increased by several orders of magnitude from the pre-urban condition.

Cumulative Duration: The results of the hydrologic modeling show that urbanization significantly increases the volume and duration of small to moderate size flows more than those for larger flows. Although the results vary by subwatershed, location within the subwatershed, and within the range of flow bins, increases in the volume and duration of runoff events range from 2 to 30 times between pre-urban and existing, and future land use conditions. Figure 3-2 provides an example flow duration histogram for a model junction in each of the three subwatersheds. Considering Thompson Creek as an example, the incremental increase in the number of hours that flows persist at certain magnitudes (i.e., duration) for the post-urban condition exceeds the pre-urban case by as much as 20 to 30 times for flows less than the 1-year peak flow magnitude. For flows greater than the 1-year peak flow magnitude, increases in duration are on the order of 2 to 3 times. Model results for Ross Creek show about a 2 to 3 times increase in volume and duration throughout the range of flows, whereas, San Tomas results show a similar trend as Thompson Creek with 2 to 20 times increases throughout its range of flows, with the largest increase in the small to moderate sized flows.

Stability Assessment

The stability assessment methodology is based on the premise that a balance among flow energy, sediment supply, and channel resilience must be maintained in order for the stream network to remain stable (MacRae, 1996). The hypothesis is that, over time, the stream channel slope and geometry co-evolved with vegetation, local physiography and climate to establish its pre-development dynamic equilibrium. By applying this method and establishing management criteria, the intent is to maintain stream sediment transport and erosion processes, not to eliminate them.

Using the flow data from the continuous simulation modeling, the stability assessment involves 1) computing the excess shear stress applied to the channel boundary, 2) computing velocity, and 3) integrating the product of excess shear and velocity over the total time (duration). The resulting integration is defined as the Effective Work Index (***W***). Excess shear stress is defined as the amount of applied shear (hydraulic force) that exceeds the critical shear stress for initial motion of bed material or erosion of bank material. This integration is done over a period of 50 years in this analysis. The assessment method then measures the potential for erosion by computing the ratio of the post-developed Effective Work Index to the pre-developed Effective Work Index. This ratio expresses the change in work done on the channel boundary between pre- and post- watershed conditions.

To gain confidence that the stability assessment method is a reliable predictor of stream channel erosion and instability, the results of the method were compared to observed field conditions classifying the current eroded state of the stream channel (low, medium or high). An empirical relationship is derived that relates model predictions to the probability of having unstable channel conditions. Through this relationship, a threshold is defined that predicts the on-set of channel adjustment and erosion, which is then used to evaluate the effectiveness of management strategies.

Figure 3-2a – Thompson Creek (Junction 5)

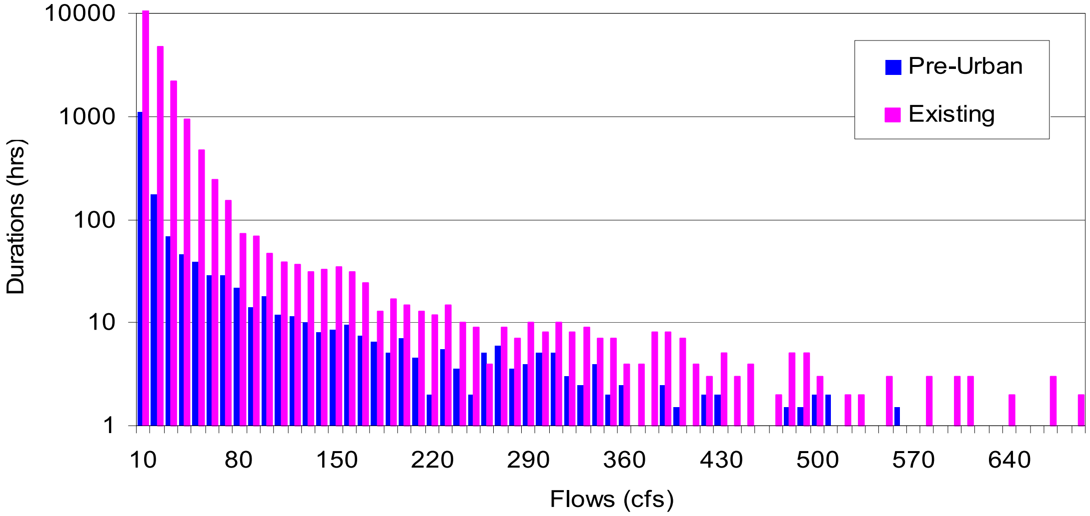


Figure 3-2b – Ross Creek (Junction 4)

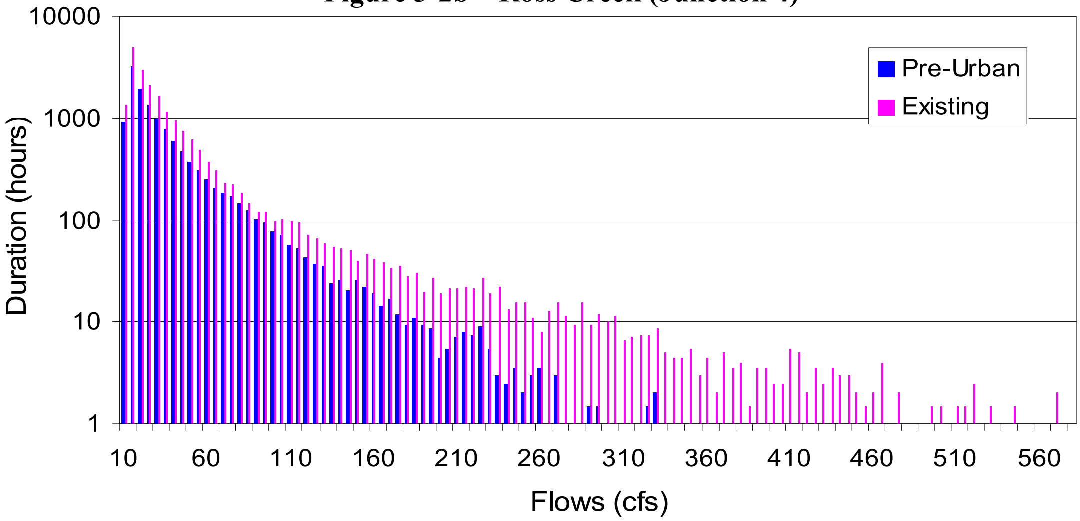


Figure 3-2c – San Tomas Creek (Junction 3)

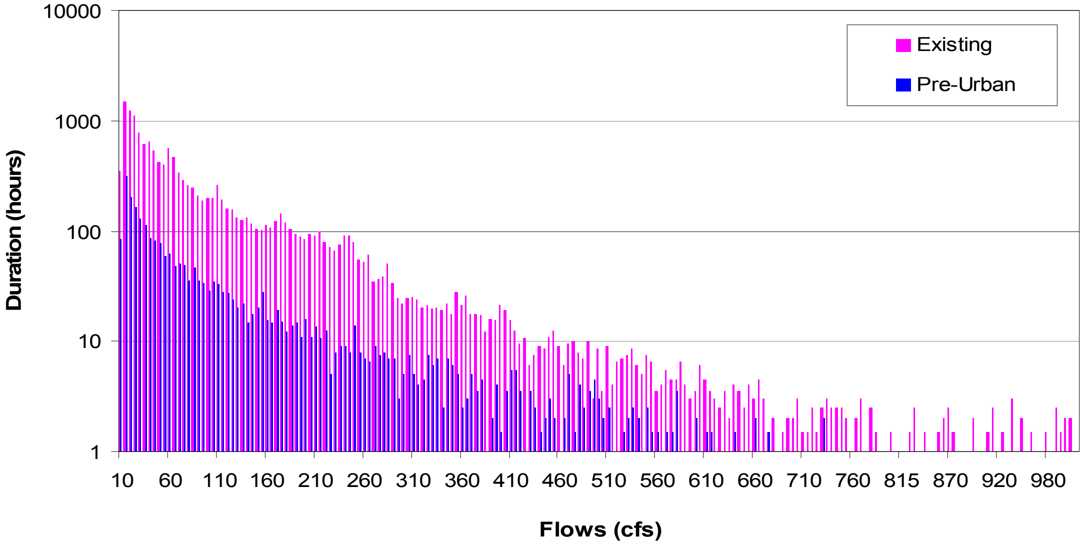


Figure 3-2 – Example Flow Duration Results for each of the Three Test Subwatersheds

Channel Stability and Thresholds. To test and verify the method, the stability assessment requires stable "*baseline"* conditions to compare to the existing conditions. Stable baseline conditions are being represented by pre-urban watershed conditions and modeling. Both the hydrologic modeling and the stream hydraulic modeling were completed using 1940s and early 1950s conditions on Ross and San Tomas Creek watersheds, and 1960s conditions on Thompson and Lower Silver Creek watersheds.

A stable channel is loosely defined as one that neither aggrades nor degrades, but instead maintains its average cross-section, planform, and profile features over time and within a range of variance. A stable channel can tolerate short-term disturbances without significant change. A disturbance of sufficient magnitude and duration that exceeds the stream's ability to self-regulate and causes the channel to begin changes is defined as the "threshold of adjustment." Under such conditions, streams can migrate, widen, or incise into underlying materials. The intent of the assessment method is to identify the threshold of adjustment where channels begin to incise or widen and the forces that cause this adjustment and accelerate the natural erosion and sediment transport processes.

Effective Work Index. The stability assessment is based on measuring the magnitude of the effective work index (***W***) by flows that exceed a specified critical value for the streambed or bank material. ***W*** is an index that represents the total work done on the channel boundary integrated over time. The index includes a velocity term to accurately represent ***W*** in units of work. The Thompson Creek study (GeoSyntec Consultants, July 2003) was updated to include the index as shown below in Equation 1 and illustrated in Figure 3-3. The effective work index is defined as follows:

$$W = C \cdot \sum_{i=1}^{n} (\tau_{bi} - \tau_c)^e \cdot V \cdot \Delta t \qquad (1)$$

Where:

W = index of total effective work done over the length of flow record per square foot of bed or bank (ft-lbs/sq-ft).

C = a constant to convert equation to dimensional or dimensionless units of work, dependent on exponent e

n = number of flow records in a histogram of flows

τ_c = critical shear stress that initiates bed mobility or shear erosion of the toe of streambanks (lbs/sq-ft)

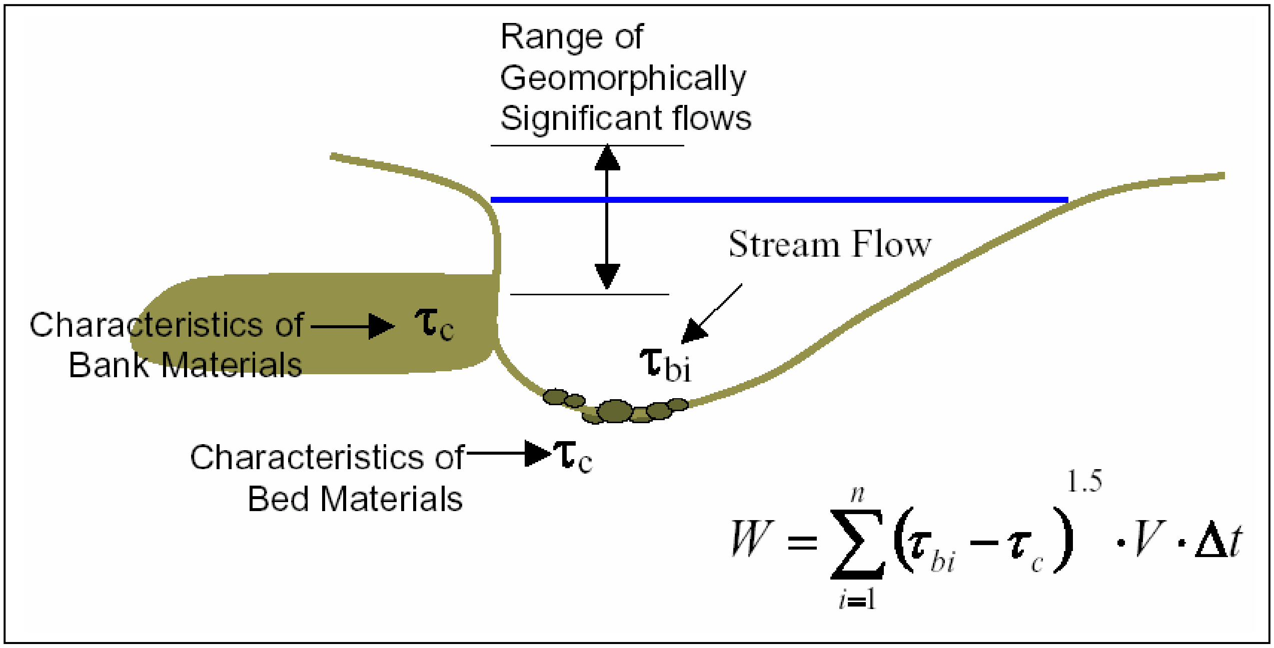
τ_{bi} = applied hydraulic shear stress, computed as ρgdS (lbs/sq-ft), on the bed or toe of banks and determined using the central channel conditions

d = depth of water (ft)	S = longitudinal slope (ft/ft)
g = gravity constant (ft/sec^2)	ρ = density of water (lb/ft^3)

e = exponent that captures the exponential rise in stream power with flow (ranges between 1 and 2.5, estimated as 1.5 for watersheds in Santa Clara Basin based on field measurements)

V = mid-channel velocity (ft/sec)

Δt = duration of flow (in seconds) for each flow record



$$W = \sum_{i=1}^{n} \left(\tau_{bi} - \tau_c\right)^{1.5} \cdot V \cdot \Delta t$$

Figure 3-3
Schematic Illustrating Effective Work Index

Critical values for the shear stress of the streambed and stream bank provide a measure of the stream's resistance to erosion. Critical values for bed material reflect the onset of sediment transport. Critical values for bank material reflect the onset of erosion of the bank, especially for weak stratigraphy layers. Selection of the critical value is based on the weakest boundary material, whether bed material or a layer of unconsolidated sands and gravels as suggested in Figure 3-3. Channels can enlarge either by downcutting into the bed or by eroding the banks and widening, or combinations of both. Streams (or boundary material) with larger critical values have more resilience to hydromodification. Observed physical properties of the stream bed and bank materials were used to determine the critical values of shear stress and velocity for those materials, based on published ranges (ASCE, 1997).

The time increment (Δt) is determined by generating a histogram of flows from the continuous hydrologic simulation results, which are hourly data. For each flow range (or "bin"), the histogram provides the count of hours or duration of time that flows are within the designated flow range. For the average flow within a bin, the depth, velocity, and shear stress are computed. Equation 1 is solved for each flow bin, to compute the incremental effective work done by that specific range of flows. When Equation 1 is summed over the 50-year flow record (histogram), the result (W) is a measure of the total effective work done on the stream channel boundary.

As an example, Figure 3-4 shows the effective work curves for the pre-urban, existing, and future watershed condition for segments of Ross Creek. The change between the existing curves and the future curves illustrate which additional urban flows will do the greatest amount of work on the stream channel and be most likely responsible for the increase in erosion in the future build-out condition. The work done at cross section RC-8, for example, shows the most dramatic

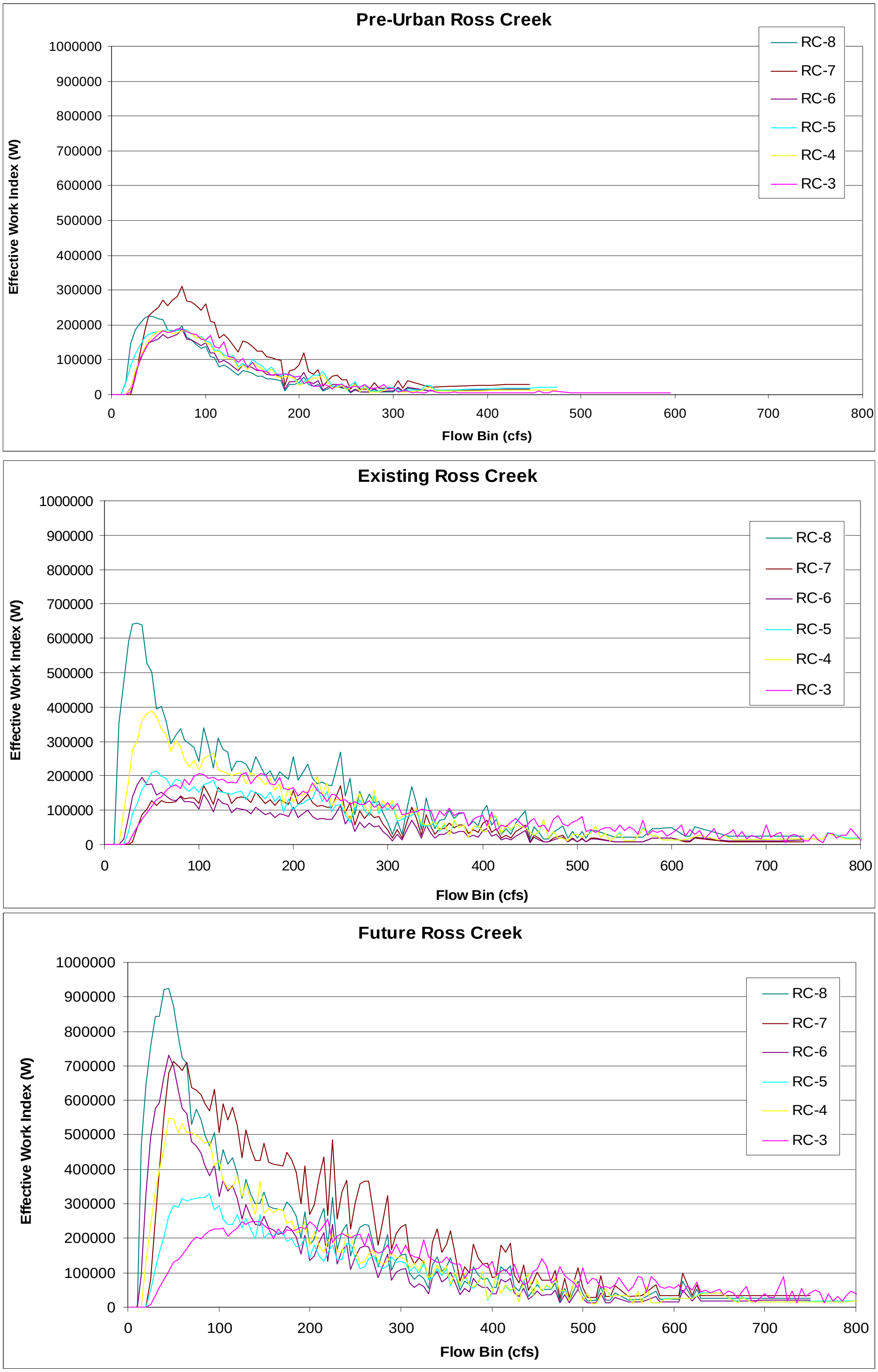


Figure 3-4
Effective Work Curves for Pre-Urban, Existing, and Future Watershed Conditions for Ross Creek

increases from pre-urban to existing to future conditions, when compared to the other cross sections. The maximum work done under future conditions is 920,000 ft-lbs/ sq-ft, a 44% increase from existing conditions.

Erosion Potential. The effective work index for stable stream channels under pre-urban conditions (or drainage areas as close to undeveloped as possible) is compared to both stable and unstable channels under urbanized conditions. The comparison, expressed as a ratio, is defined as the Erosion Potential (Ep) (MacRae, 1992, 1996).

For the stability analyses in this report, the Ep ratio was defined as:

$$Ep = \frac{W_{existing}}{W_{pre-urban}} \qquad (2)$$

$W_{existing}$ = work index for a stream section under existing conditions (could be either stable or unstable)

$W_{pre\text{-}urban}$ = work index for a stream section under pre-urban conditions (baseline assumed to be stable)

Predicting the erosion potential for future development projects and for management purposes, the Ep ratio would be written as:

$$Ep = \frac{W_{post}}{W_{pre}} \qquad (3)$$

W_{post} = work index estimated for the post-project condition

W_{pre} = work index measured for the pre-project condition

A conceptual diagram defining the concept of Ep is provided in Figure 3-5. The effective work done for the pre-project and post-project condition is the area under the shear stress-time curve, above the threshold critical shear stress. Ep is represented by the ratio of the area under the post-project curve to the area under the pre-project curve.

In the stability assessment, the computed work indices for the pre-urban and existing land use conditions and the resulting Ep values at a particular stream cross-section were then compared to the field classified erosion condition (stable/low or medium/high level of erosion). The numeric value of each parameter was plotted by group on a vertical chart referred to as the Erosion Potential Chart.

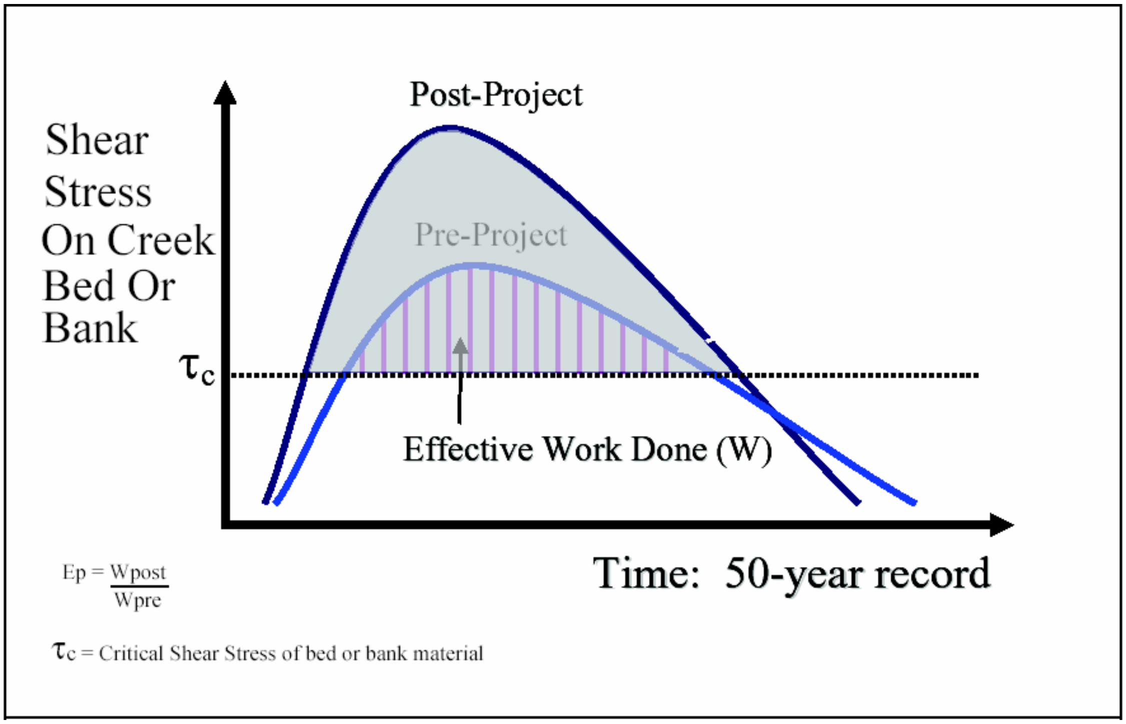


Figure 3-5
Definition of Ep Ratio

Figure 3-6 presents the Erosion Potential Chart for Thompson Creek (TC), Ross Creek (RC), and San Tomas Creek (ST), which shows a strong correlation between computed Ep and the field-designated erosion classification. These three subwatersheds include data and analysis on Yerba Buena Creek (YB) and East Ross Creek (ER) in the Thompson Creek and Ross Creek subwatersheds, respectively. Those sections classified as having medium/high observed erosion characteristics plot on the chart above those classified as stable/low with only two outliers. Not including the two extreme outliers, the lowest Ep computed for sections with medium/high erosion is 1.5, whereas the highest Ep value for sections classified as stable /low is estimated as 1.6. Comparing the results between all three subwatersheds, the Ep values at which cross-sections transition from stable to unstable rates of erosion are similar.

It is unrealistic to believe that stream channels will behave such that a single Ep threshold value can be specified (such as 1.5) that, if exceeded, would always result in unstable channel conditions; or conversely, if less than would always be stable. Because of natural variability in stream attributes and also considering uncertainties in the methodology, the threshold of adjustment was represented as a probability relationship described in the following section.

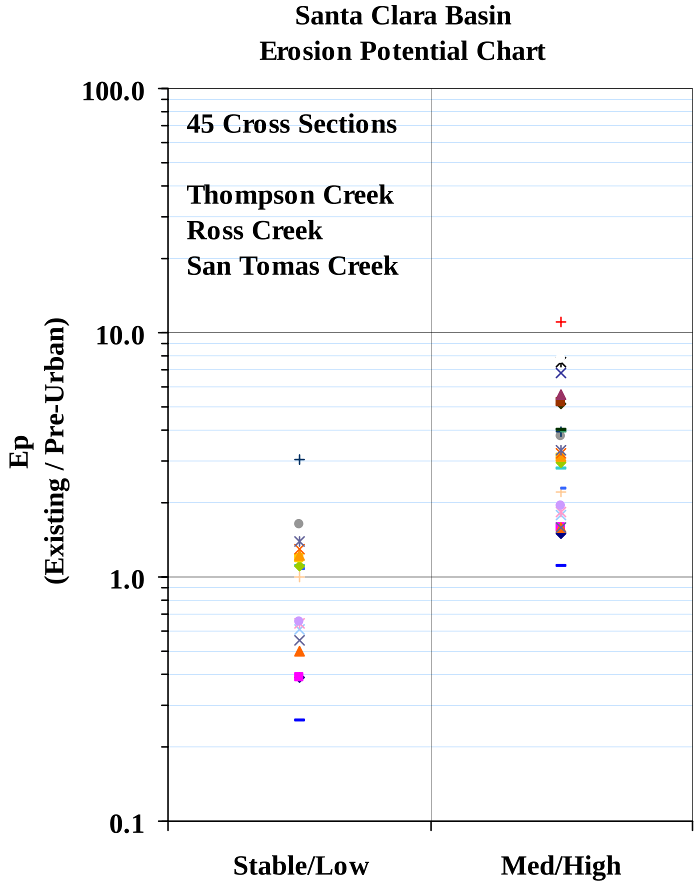


Figure 3-6 Erosion Potential Chart for Santa Clara Basin Streams

Logistic Regression. Logistic regression is a methodology that can be used to predict the probability, or likelihood, of having a stream segment become unstable in a two discrete state model (stable, unstable), based on a measure of Ep. Appendix E briefly describes how logistic regression is applied to stream stability issues.

Figure 3-7 presents the logistic plot of the erosion potential (Ep), based on the pooled data from all three subwatersheds. Forty-five cross sections spread out between the three subwatersheds were ultimately used in the final assessment and plotted in Figure 3-7. This curve represents the probability of having a stream segment become unstable given a value for Ep. If for example the Ep was computed to be 1.63, the chance of having unstable channel conditions is 50:50. Channel sections with Ep values in excess of 2 have a 77 percent chance of becoming unstable.

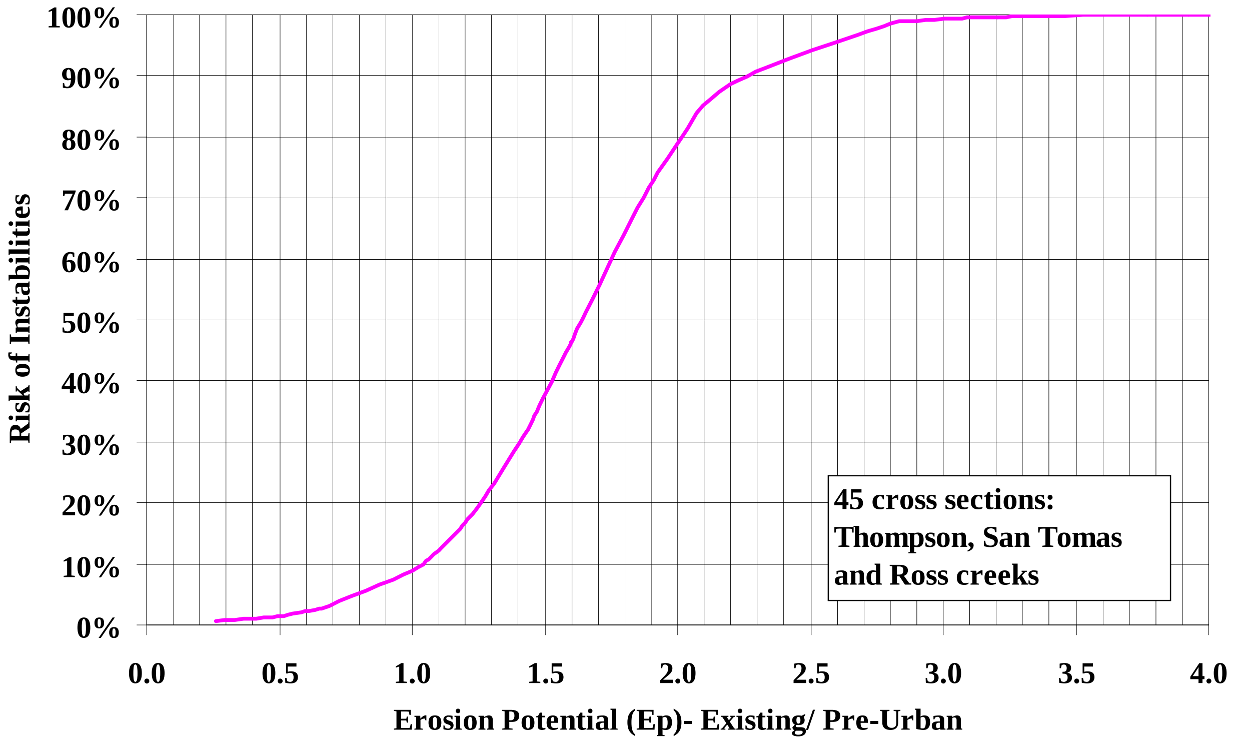


Figure 3-7 Probability of a Stream Segment Becoming Unstable, Based on Logistic Regression of Erosion Potential (Ep) Values

From a risk management perspective, Ep values between 1.0 and 1.2 reflect the portion of the logistic plot where the probability of becoming unstable begins to increase. For example, an Ep of 1.0 to 1.2 indicates that the chance of a segment becoming unstable range from 9 to 17 percent. Above an Ep of 1.4, the chances increase substantially (i.e. >25 percent).

One way to understand the meaning of "risk of instability" is to think about it in terms of the number of streams that could still become unstable even with flow controls in place. For example, a 25% risk implies that 1 in 4 streams could become unstable and lead to erosion problems even with control in place. A 9% risk implies that 1 in 11 streams could still become unstable even with controls, while a 17% risk implies that 1 in 6 stream could become unstable.

Analysis of Critical Flow (Qc). Critical flow is defined as the stream flow that produces the critical shear stress that initiates bed movement or that erodes the toe of stream banks. When measuring Qc for other streams and future studies, Qc should be based on the weakest boundary material – either the bed or bank. Table 3-3 lists the estimated critical flows at selected cross sections in Thompson and Ross Creeks.

Computed critical flows for Thompson Creek ranged from 3 cfs to 40 cfs depending on the location in the stream, using average critical shear of 0.14 lbs/sq-ft for most sections. However, based on the sediment sampling data collected in Thompson Creek, critical flows were estimated to range from 1 cfs to 18 cfs. Computed critical flows for Ross Creek ranged from 15 cfs to 25 cfs, using critical shear values ranging from 0.23 to 0.38 lbs/sq-ft depending on location. The critical shear stresses for Ross Creek are higher than those used for Thompson because the size of the bed material is larger. The large values observed for cross sections TC1-1 and TC1-2 are a result of the channel having been engineered with grade controls installed so that higher flows could be accepted.

Table 3-3
Summary of 2-Year Peak Flows and Estimated Critical Flow Values

Subwatershed and Location	Cross Section	Critical Flow (Qc) in Stream (cfs)	% of 2-Year Peak Flow in Stream
Thompson Creek			
J-1	TC5-7	10	18
J-5	TC5-1, 5-2 & 5-3	3, 5, 7	2, 3, 4
J-12	TC1-1, 1-2	40, 40	8
Yerba Buena	YB-6, YB-7	5, 4	7, 6
	YB-2, YB-4	3, 10	5, 18
Ross Creek			
J-1	RC-1, RC-2	25, 25	12
J-5	RC-6, RC-8	20, 15	14, 11

a) Thompson Creek 2-year peak flows were generated from synthetic design storm hydrographs under pre-urban land use conditions.
b) Ross Creek 2-year peak flows were generated from the 50-year continuous model runs for the pre-urban condition.

In order for the critical flow to be useful to dischargers in design of hydromodification control structures, the critical flow in the stream must be partitioned or related to an on-site project based variable. For this purpose, the in-stream critical flow was related to the pre-urban 2-year peak flow in the stream. The critical flow was generalized as being 10% of the 2-year peak flow under undeveloped land use conditions.

The 2-year peak flows was estimated using a balanced hyetograph approach for 24-hour storm duration in conjunction with design storm rainfall depths following the SCVWD *Hydrology Procedures* manual (1998) guidance.

Findings

Effective Work

- The predicted effective work index (***W***) is capable of distinguishing between stable stream sections (pre-urban, stable/low existing conditions), and unstable stream sections (medium/high existing conditions).
- In all watersheds studied, the more frequent small to moderate magnitude flows have the greatest influence on channel shape and erosion potential.

- The critical discharge (Qc) at which bed material begins to move in quantity is about 10 to 15 cfs for Thompson Creek and 20 to 25 cfs for Ross Creek. In both instances, it is roughly 10 percent of the pre-urban 2-year peak flow in the stream.

Erosion Potential (Ep)

- The Ep methodology is capable of distinguishing stable/low eroding conditions from medium/high eroding conditions for each of the three subwatersheds (including East Ross Creek and Yerba Buena Creek).
- The Ep ratio between the subwatersheds is similar such that the Ep data for all three subwatersheds can be pooled together to evaluate the threshold of adjustment.

Threshold of Adjustment

- The logistic regression analysis provides a statistical tool to relate the likelihood of a stream channel becoming unstable to the computed Ep ratio.
- An Ep ≤ 1.0 is recommended as the in-stream target value for HMP management. From a risk management perspective, the chance of a stream becoming unstable at an Ep of 1.0 is 9%, meaning 1 in 11 streams could become unstable even with controls. The in-stream erosion potential must be measured considering the effects of the cumulative changes that take place in a watershed.

Implications for a Watershed Wide Standard

- The watersheds studied are not significantly different to warrant separate hydromodification standards, criteria, and thresholds. Differences between watersheds are accounted for in the assessment methodology (see Section 3.4).

3.4 DEVELOPING A BASIN WIDE STANDARD

One relevant question to this discussion is “why do the results for Ross Creek seem to be consistent with the results for Thompson Creek?” These two subwatersheds have different climatic, physiography, soils and vegetation characteristics; and geomorphic theory suggests that these stream systems could have different management strategies. A related question was raised during the preparation of the Literature Review - that is, if Santa Clara Basin conditions are different from other regions, can hydromodification assessment methods developed in other regions be applied to Santa Clara? A member of the Expert Panel[5] commented that this is a reasonable question to ask but one that can be resolved. If models are calibrated to local conditions and the relevant processes are described adequately, methods from other regions in North America can be used. In other words, if the hydromodification assessment methodology incorporates the relevant physical processes, then differences between regions - or differences between subwatersheds - are accounted for and a model can produce consistent results.

Factors Used to Justify a Basin Wide Standard

The factors that were considered to compare the results for the test watersheds include the estimated erosion potential values and the range of flows to be managed for hydromodification.

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[5] The Peer Review Team includes Professor Matt Kondolf, UC Berkeley; Professor Tom Dunne, UC Santa Barbara; and Professor Brian Bledsoe, Colorado State University.

Erosion Potential. One important element of estimates of erosion potential is that the range in values does not differ significantly between subwatersheds. Even though the subwatersheds have different climatic, physiography, soils and vegetation characteristics; the erosion potential (Ep) is normalized on each subwatershed's own baseline conditions. That is, the denominator of the Ep value is the work index (or amount of work done by stream flows) for the pre-urban condition of that subwatershed. In this way, the difference in critical shear stress between stream systems is accounted for in the baseline condition. Different stream systems can have different absolute values of work (higher or lower), but have similar tolerances for change.

Range of Flows. Critical flow (Qc) is defined as the stream flow that produces the critical shear stress (τc) and initiates bed movement or erodes the toe of streambanks. The critical flow in the stream must be partitioned or related to an on-site project based variable. The in-stream critical flow was related to the pre-urban 2-year peak flow and was generalized as being 10% of the 2-year pre-urban peak flow. The results for Thompson Creek and Ross Creek are similar so that separate definitions for Qc are not required

The upper limit on the range of storms has been determined by evaluating the percent that different flow magnitudes contribute to the total work done on the channel boundary. The low flows contribute the most work, whereas high flows contribute less. Approximately 90% of the total work on the channel boundary is done by flows between Qc and the pre-urban 10-year peak flow magnitude. Flows greater than the 10-year peak flow contribute only 10% of the total work. The range of storms analysis is discussed further in Chapter 4.

Conclusions. The results indicate that Ross Creek and San Tomas Creek are not significantly different from Thompson Creek and do not warrant a separate hydromodification standard, criteria, or threshold of adjustment. Although the absolute magnitude of the computed work indices is different, the Ep ratio is consistent between subwatersheds. The transition between stable and unstable channels occurs between Ep values of 1 and 1.2.

The estimates for the range of storms to manage (Qc to the 10-year pre-urban peak flow) are consistent between subwatersheds. The value of Qc is dependent on the bed and bank material characteristics of each subwatershed. However, approximating Qc as 10% of the 2-year pre-urban peak flow is generally consistent between subwatersheds for HMP management purposes.

One of the goals of this study was to develop an analytical method that could be used to predict hydromodification impacts from development. These studies were necessarily conducted in subwatersheds with primarily urban development without other potentially overlapping impacts like dams/reservoirs, gravel mining, etc. These test subwatersheds allow for the evaluation of urban impacts and the effectiveness of potential solutions. Implementation of control measures that mitigate hydromodification impacts from urbanization will not address problems generated from other sources of impacts, such as dams and reservoirs.