APPENDIX I - Identification of a Site-Specific Low Flow Threshold

If allowed by the governing Copermittee, project proponents have the option to use a site-specific low flow threshold for individual projects instead of 10% of the 2-year peak flow specified in the HMP.

A project proponent may assess the viability of pursuing a site-specific low flow threshold based on the results of a planning-level analysis that is presented in this Appendix. The planning-level analysis consists of a critical flow sensitivity assessment, which provides the project proponent with a general indication that a site-specific low flow threshold may be appropriate, but is not sufficient to quantify the threshold. The stepwise approach is consistent with that developed for the San Diego County HMP (2011).

The demonstration of an applicable low flow threshold must be performed based on field geomorphic evaluation, non-uniform hydraulic modeling, and sediment continuity modeling. This Appendix provides general concepts on these topics. A person knowledgeable in sediment processes should be consulted if the project proponent desires to take the next step and establish a site-specific low flow threshold.

A. For Planning Purposes Only: Simplified Stepwise Approach

For initial planning purposes, the developer may run the desktop-level analysis using the proposed empirical equations and assess the viability of pursuing a site-specific low flow threshold. To establish viability of a site-specific threshold, the applicant may perform and document the findings of each of the following six steps.

The simplified stepwise approach is only provided as an attempt to assist the applicant with a simplified method. The uncertainty associated with each of the variables of the simplified approach can potentially falsely influence the results. It is the applicant's responsibility to analyze the results and the geomorphic environment of the downstream channel before attempting to pursue a site-specific low flow threshold.

Step A-1: Identify the Typical Range of Rainfall Conditions for the HMP Area

The purpose of Step 1 is to identify the mean annual precipitation at the project site based on existing records from a nearby station. The mean annual precipitation serves as an input to characterize the dominant discharge for the receiving channel. Based on 70+ years of District SMR rainfall records, the mean annual precipitation ranges from 11.6 to 20.6 inches in the SMR. The developer should identify on Figure 2 of the main document, the meteorological zone where the project site is located, and subsequently refer to **Table 12** to select the associated mean annual precipitation.

Table 12 - SMR Mean Annual Precipitation per Meteorological Zone

Meteorological Zone	Mean Annual Precipitation (in inches)
Eastern Slopes	14.7

Temecula Valley	15.8
Western Plateau	20.6
Wildomar / North Murrieta	11.6

Step A-2: Identify a Range of Typical Receiving Channel Dimensions for Each Watershed Area

Empirical relationships have been developed to express channel dimensions (width, depth, and to a lesser extent, gradient) as a function of the dominant discharge. For undeveloped channels in semi-arid parts of the U.S. such as in the SMR, dominant discharge can be approximated by the 5-year discharge flow.

Step A-2.a – The dominant discharge, Qbf, assumed to be approximately equivalent to the 5-year peak discharge (Q5), may be estimated using the USGS regional regression for undeveloped watersheds in the South Coast Region (Waananen and Crippen, 1977). This equation calculates Q5 (cfs) as a function of watershed area (sq. mi.) as determined in Step 2, and mean annual precipitation (MAP, in/yr) as determined in Step 1. The relationship is:

$$Q_5(cfs) = 0.4 \cdot [Watershed\ Area\ (sq.mi)]^{0.77} \cdot [Mean\ Annual\ Precipitation\ (inches)]^{1.69}$$

Step A-2.b –Identification of the width and the depth of each channel reach: The developer may iteratively identify the type of channel as defined in **Table 13** that most corresponds to each individual channel reach that is selected within the domain of analysis (defined in Appendix C). In addition to the channel type, **Table 13** identifies the source and the empirical channel geometry relationships. Empirical relationships were developed based on stream geometry and hydrology in Southern California.

Table 13 - Empirical relationships for Channel Dimensions

Channel Type	Source	Empirical Channel Geometry Relationships
Undeveloped channels in Southern California – narrow, deep, and steep dimensions	Coleman et al., 2005	$Width(ft) = 0.6012 \cdot Q_{bf}^{0.6875}$ $Depth(ft) = 0.3854 \cdot Q_{bf}^{0.3652}$ Q_{bf} in cfs
Gravel channels – wide, shallow, flat braided dimensions	Parker et al., 2007	$Width(m) = 4.63 \cdot \frac{Q_{bf}^{2/5}}{9.81^{1/5}} \cdot \left[\frac{Q_{bf} \cdot d_{50}^2}{\sqrt{9.81 \cdot d_{50}}}\right]^{0.0667}$ $Depth(m) = 0.382 \cdot \frac{Q_{bf}^{2/5}}{9.81^{1/5}}$

Channel Type	Source	Empirical Channel Geometry Relationships
		Q_{bf} in the bankfull discharge in m³/s d_{50} is the diameter of median channel material in m
Medium width, depth, and gradient channels	Hey and Thorne, 1986	$Width(m) = 2.73 \cdot Q_{bf}^{0.5}$ $Depth(m) = 0.22 \cdot Width^{0.37} \cdot d_{50}^{-0.11}$ Q_{bf} in the bankfull discharge in m³/s d_{50} is the diameter of median channel material in m

Step A-3.c – Compute a channel slope using Manning's equation such that the wetted cross-sectional area at bankfull depth conveys the dominant discharge. Manning's equation is expressed as:

$$Q = 1.486 \cdot \frac{A \cdot R^{0.67} \cdot \sqrt{s}}{n}$$

Where:

- Q = Flowrate (cfs)
- A = Cross-Section Flow Area (ft2)
- R = Hydraulic Radius (ft) = A / P
- P = Wetted Perimeter (ft)
- s = Energy Gradient Assumed Equal to Longitudinal Slope (ft/ft)
- n = Manning Roughness (unitless)

For planning purposes, the Professional Engineer can assume a Manning Roughness value of 0.025, corresponding to a non-vegetated, straight channel of small slope, after aging whose bed material is composed of colloidal alluvial silt (ASCE No.77, 1992). However, it is suggested that the Professional Engineer determine the retardance coefficient from **Table 14**. This reflects the small, ephemeral receiving channels which are prevalent in Southern California. A different Manning Roughness value may be used only if it has been previously approved by the governing Copermittee. A sensitivity analysis performed in the San Diego HMP found that the retardance coefficient had little effect on the estimated critical shear flow rate.

Table 14 - Critical Shear Stress per Type of Bed Material (Source: ASCE No.77, 1992)

Material	n	Clear Water		Water Transporting Colloidal Silts	
		V (fps)	τ (lb/ft2)	V (fps)	τ (lb/ft2)
Fine sand, colloidal	0.020	1.50	0.027	2.50	0.075
Sand loam, noncolloidal	0.020	1.75	0.037	2.50	0.075
Silt loam, noncolloidal	0.020	2.00	0.048	3.00	0.11
Alluvial silts, noncolloidal	0.020	2.00	0.048	3.50	0.15
Ordinary firm loam	0.020	2.50	0.075	3.50	0.15
Volcanic ash	0.020	2.50	0.075	3.50	0.15
Stiff clay, very colloidal	0.025	3.75	0.26	5.00	0.46
Alluvial silts, colloidal	0.025	3.75	0.26	5.00	0.46
Shales and hardpans	0.025	6.00	0.67	6.00	0.67
Fine gravel	0.020	2.50	0.075	5.00	0.32
Graded loam to cobbles when noncolloidal	0.030	3.75	0.38	5.00	0.66
Graded silts to cobbles when colloidal	0.030	4.00	0.43	5.50	0.80
Coarse gravel, noncolloidal	0.025	4.00	0.30	6.00	0.67
Cobbles and shingles	0.035	5.00	0.91	5.50	1.10

Step A-3: Identify a Range of Typical Channel Material for Receiving Channels

The developer should identify the weakest predominant type of bed material in each section of the receiving stream channel within the domain of analysis. A simple identification from aerial imagery, available photography, or existing technical documentation is deemed sufficient for planning purposes, or a field review or a geotechnical investigation can be used. The developer should subsequently identify the critical shear stress associated with each type of predominant bed material using **Table 14**. **Table 14** presents a nonexhaustive list of critical shear stresses for typical channel materials and covers the range of critical shear stresses to be encountered in the SMR. **Table 14** may be used for planning purposes only.

Appropriate references for critical shear stress values are provided in ASCE No.77 (1992) and Fischenich (2001). To account for the effects of vegetation density and channel irregularities, the applied shear stress can be partitioned into form and bed/bank roughness components, and the lowest value of d50 be used for calculations. Other references include the procedure for application of allowable velocity to determine the critical shear stress or equivalent allowable velocity associated with a specific type of bed material. Design of Open Channels, TR-25 (USDA, 1977) will guide the developer through the allowable velocity approach, which relates allowable velocity to sediment concentration, grain diameter of the noncohesive boundary material, and plasticity index and soil characteristics for cohesive boundary material. Another effective reference is the National Engineering Handbook Part 654, Chapter 8, which contains the Shields diagram and describes the allowable shear stress approach (NEH, 2007).

Step A-4: Identify the Flow Rate at Which Boundary Shear Stress Exceeds Critical Shear Stress for the Channel and Material

The tractive force theory was initially described in Shield's diagram (1936) and further translated into an equation by the Bureau of Reclamation (1987). The tractive force theory establishes that bed material is being displaced when the shear stress applied on the boundary of a particle of bed material exceeds the critical shear stress associated with that particle. The average boundary shear stress on a particle of bed material may be expressed as:

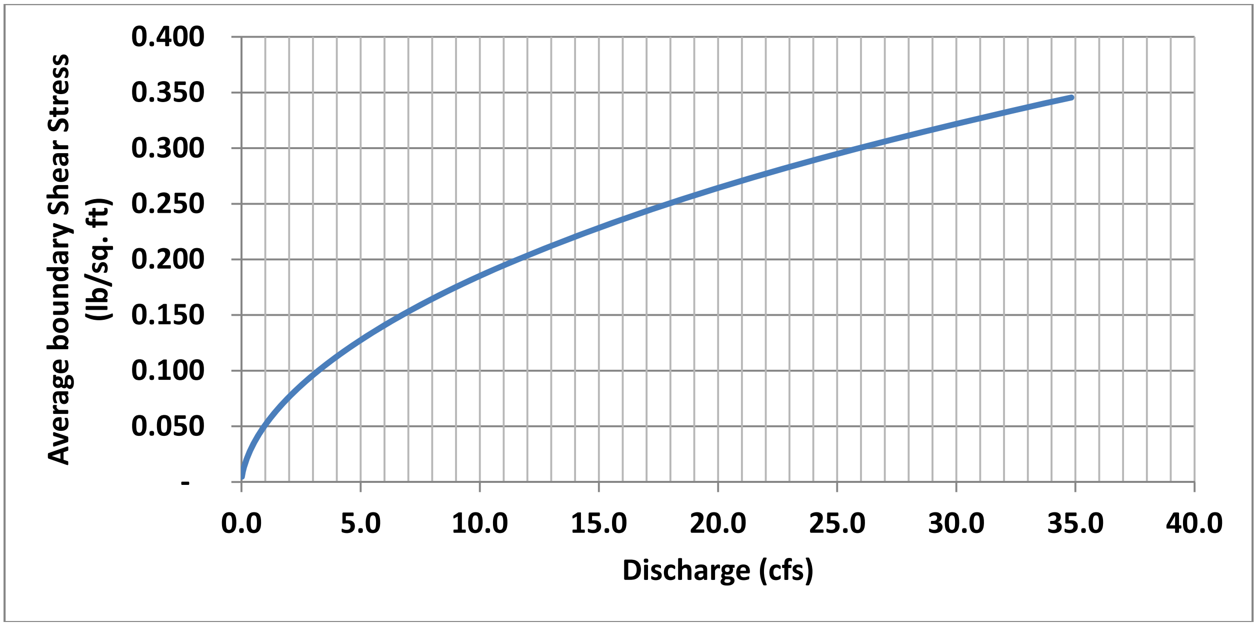
$$\tau = \gamma \cdot R \cdot s$$

Where:

- τ = Effective Shear Stress of d_{50} from sieve analysis (lb/ft2)
- γ = Unit Weight of Water (62.4 lb/ft3)
- R= Hydraulic Radius (ft) as determined in Step 2
- s = Longitudinal slope (ft/ft) as determined in Step 2.c

Using Manning's equation for the established channel cross-section, roughness, and gradient, the flow depth is iterated to produce a shear stress rating curve for each of the channel section selected within the domain of analysis. A shear stress rating curve correlates the average boundary shear stress to a discharge, which can be as high as the dominant discharge in this exercise. For the purpose of the exercise, an example shear stress rating curve is shown in **Figure 19**. The example shear stress rating curve was developed with the following parameters: s= 0.005 ft/ft; n= 0.035; side slope = 1H: 1W; bankfull depth = 1.51 feet; bankfull width = 7.91 feet.

Figure 19 - Example Shear Stress Rating Curve



Based on the critical shear stress identified in Step 4, the Professional Engineer should identify on each shear stress rating curve, Qcrit, or the flow rate at which boundary shear stress equals critical shear stress.

Step A-5: Express Critical Flow As A Function of Q2

The applicant may use the USGS regional regression of the 2-year peak discharge for the South Coast Region (Waananen and Crippen, 1977) to determine the 2-year peak discharge in each channel reach selected within the domain of analysis. The regression equation is expressed, as follows:

$$Q_2(\text{cfs}) = 0.14 \cdot [\text{Watershed Area (sq. mi)}]^{0.72} \cdot [\text{Mean Annual Precipitation (inches)}]^{1.62}$$

The critical flow (Qcrit) is expressed as a function of Q2 to remain consistent with the standardized relationship stated in existing HMPs throughout California.

Step A-6: Identify the Most Conservative Low Flow Threshold

In a final step, the Professional Engineer should summarize in a tabular format the findings of the stepwise approach applied to each section of stream channel. An example of such tabular representation is showcased in **Table 15**, in which critical flow rates are grouped by type of channel material.

Table 15 - Summary Table of Critical Flow Rates per Section of Stream Channel

Drainage Management Area	Trib Area	Mean Annual Precip	5-year Flowrate	2-year Flowrate	Critical Flowrate	Low Flow Threshold	Bankfull Width	Bankfull Depth
	A	MAP	Q5	Q2	Qcrit	Qcrit/Q2	W	D
	sq mi	in/yr	cfs	cfs	cfs	% of Q2	ft	ft
τ_{crit} = 0.025 lb/ft2, sand bed (low end)								
Section A1	1	15.8	42.5	12.2	0.296	**2.4%**	7.91	1.51
τ_{crit} = 0.05 lb/ft2, sand bed (high end)								
Section A2	1	15.8	42.5	12.2	0.947	**7.7%**	7.91	1.51
τ_{crit} = 0.12 lb/ft2, gravel								
Section A3	1	15.8	42.5	12.2	4.452	**36.4%**	7.91	1.51

In the above example, for Section A1, the ratio between the critical flow and the 2-year peak flow is computed as: (0.296 cfs) / (12.2 cfs) = 0.024 = 2.4%.

From the summary table, the Professional Engineer should identify the most conservative low flow threshold among all downstream sections. For instance, in the presented example, the Engineer should select 2.4% Q2 as the site-specific low flow threshold. In this instance, a site-specific low flow threshold would not be advantageous for the project.

B. For Consideration and Approval by the Governing Copermittee: Full-Scale Geomorphic Assessment

For consideration and approval of a site-specific low flow threshold by the governing Copermittee, demonstration must be established based on field geomorphic evaluation, nonuniform hydraulic modeling, and sediment continuity modeling. A person familiar with sediment transport should be consulted if the project proponent was to establish a site-specific low flow threshold.

The field geomorphic assessment, to be performed within the domain of analysis, should identify the geometry of each selected cross-section and characterize the associated bed material. The geomorphic evaluation requires surveying the cross-section and longitudinal profile geometry of the active channel, estimating the hydraulic roughness of the channel, and evaluating the critical shear stress (pounds per square foot) of the most sensitive bed and bank material. For non-cohesive material, a Wolman pebble count or sieve analysis is used to obtain a grain size distribution, which can be converted to a critical shear stress using an empirical relationship or reference tables in the literature. For cohesive material, an in-situ jet test or reference tables are used. For banks reinforced with vegetation, reference tables are generally used.

The site-specific hydrologic and hydraulic evaluation should determine the 2-year peak discharge Q2 based on a flow gage record in the receiving stream or a continuous hydrologic model, if available. In computing Q2, the original condition of the watershed tributary to the stream, before development, shall be considered. This provides a means of apportioning the critical flow in a channel to individual projects (on a pro-rata area basis) that discharge to that channel, such that cumulative discharges do not exceed the critical flow (Qcrit) in the stream of concern. This flow apportionment must be provided as a part of the analysis by the Professional Engineer.

The applicant must demonstrate through a stream stability impact assessment that the changes to both the amount of sediment transported and the amount of sediment supplied to the stream, will maintain the general trends of aggradation and degradation in the impacted channel reaches, which are representative of the dynamic equilibrium of a stream channel.